ELECTRI International Foundation

Green Energy Challenge

Henning Building

The Pennsylvania State University

NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION

ELECTRI INTERNATIONAL

THE FOUNDATION FOR ELECTRICAL CONSTRUCTION INC.

April 20, 2015

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Project Summary

Executive Summary

The Pennsylvania State University's NECA Student Chapter created a comprehensive energy retrofit proposal for the Henning Building, located on the Penn State University Park in State College, PA. The client, The Pennsylvania State University, has expressed the need for a simple payback period of 10 years with no budgetary limitations as long as the project pays back within the required payback period. The total cost of all upgrades will amount to $527,437, the annual energy savings will be $46,992 annually.

The goal of the project was to improve the energy efficiency of the Henning Building, which would benefit from improved resiliency to loss of utility through back-up power supply and micro grid capability, while also increasing the comfort inside the facility for the faculty and students. The lessons learned by the students and staff will translate to energy saving habits on and off Penn State's campus.

The major systems and analyses included in the scope of work are as follows:

- Existing energy analysis and benchmarking
- LED luminaire and lighting control upgrade
- Photovoltaic array design and implementation

The project will be completed over the summer. We have hired an electrician at the standard rate of $60/hr.

The proposed systems will continue to contribute to Penn State's commitment to reducing greenhouse gas emissions from its facilities. The energy efficient lighting system, photovoltaic energy system, and *energy monitoring and feedback system* will be a showcase of sustainable leadership within Penn State and among other colleges in the region. The financial and environmental benefits will be used to develop further business opportunities in the region.

Mission Statement

Our team is committed to maximizing utility for our client in any given locale. Combining the best of innovative design with technological reform, our dedicated and cohesive team is able to find a solution for our clientele no matter how difficult the challenge.

Summary of Client

The Pennsylvania State University's history is rooted in taking care of the earth. Once founded in 1855 as a small agricultural college, Penn State is now urbanizing and expanding, but holding to its roots by making the promise to reduce energy consumption on its campuses. Penn State's Greenhouse Gas Emission Reduction Strategy has provided a plan to reduce the energy used by Penn State facilities by increasing building energy efficiencies, promoting energy awareness and conservation, improving non-energy initiatives such as recycling and transportation, and utility improvements. As reported by the sustainability department at Penn State, greenhouse gas emissions have been reduced by 17.5% since 2005 and aims to reach 35% reductions by the year 2020. The steam plant is being converted from coal to natural gas, reducing emissions from the plant by 50%. Transportation vehicles are being converted to compressed natural gas and electric motors rather than gasoline and diesel. Recycling and compost efforts divert 75% of solid waste from landfills. Energy efficiency improvements within the building have been focused on lighting, controls, and energy alternatives. This enables campus to expand without the need for additional energy.

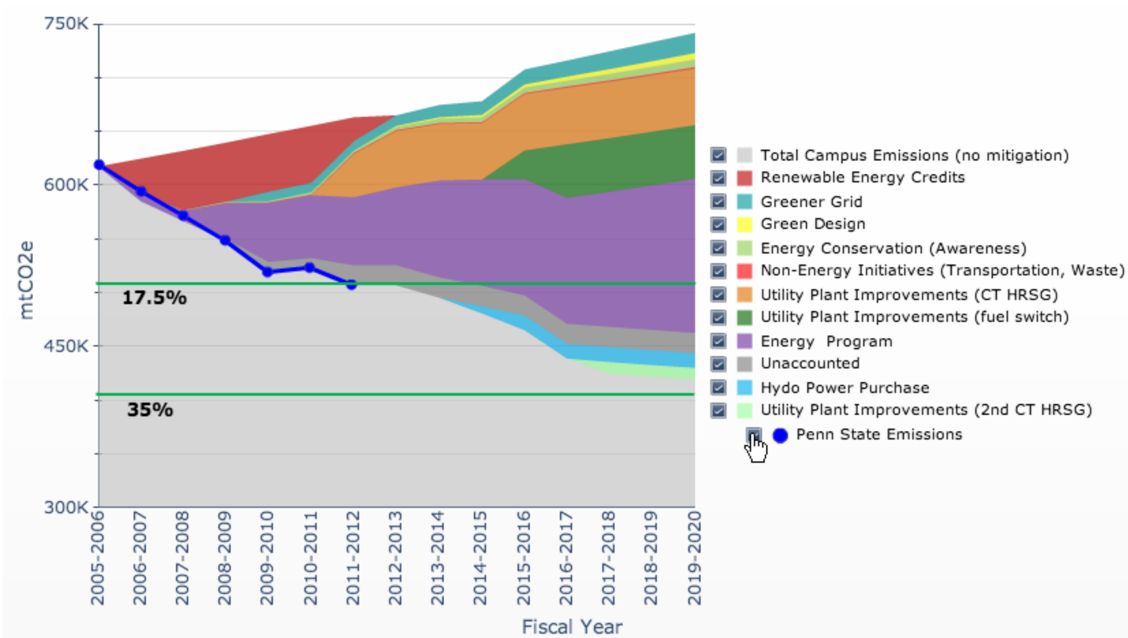

Figure 1: Penn State Greenhouse Gas Reduction Strategy

The Penn State University Park (UP) campus uses steam heat warm its buildings during the long Central Pennsylvania winters. Enough excess energy from this process is stored as electricity to act as an emergency system for campus' entirety. Therefore, should there ever be a fault in our system, recycled and stored energy would be used, eliminating our dependency in the system. This concept was the focus of the 2015 Green Energy Challenge. After meeting with Office of Physical Plan managers about which building on campus had the highest urgency for energy resiliency, the Henning Building became a particular interest. The Henning Building brings Penn State back to its farming roots, housing the Department of Animal Sciences and Department of Veterinary and Biological Sciences.

The Henning Building has been the home of the Animal Sciences Department since 1969. It houses mainly offices, conference rooms, animal facilities, and laboratories. The facility is open from 7am to 11pm during the week, but has 24 hour card access to those working in the labs. The building remains open during the summer and winter breaks, but for reduced hours to allow for admissions and other offices to remain open. The Henning Building is three stories tall. Since its construction, an additional glass walkway was constructed to allow indoor access to the Agricultural Science and Industries Building. Even with the addition, few improvements have been made to the Henning Building and currently remains outdated in terms of energy consumption.

Many of the labs and facilities exist to house the research of life. In the misfortune of a power outage, it is our duty to provide these animals with the means to live. For this reason, it is imperative there are no faults in Henning Building's back-up power system. The Henning Building has an opportunity to be a focus for energy efficiency improvements on Penn State's campus. The age of the facility and systems in place make an ideal opportunity for upgrades to take place. With Henning Building's requirements in terms of backup power, energy improvements and renewable energy systems will provide a great energy education tool for the campus. These improvements can be used as an example for other research facilities on campus, allowing knowledge and resources to expand without the need for additional energy.

Team Members

Nicholas Kolesar

Energy Audit & Outreach

Gabrielle Reese

Micro grid

Haley Bendis

Lighting

Kevin Clement

Construction Management

Jiye Choi

Energy Audit - Team Member

NICHOLAS SCOTT KOLESAR

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EDUCATION

Bachelor of Science in Energy Engineering **GPA: 3.06**

Bachelor of Science in Energy Business & Finance: Energy Systems Option **May 2016**

Minor in Environmental Engineering
Minor in Sustainability Leadership
The Pennsylvania State University, University Park, PA

WORK EXPERIENCE

National Energy Leadership Corps – Intern (University Park, PA) **May 2014 – Present**

- Leader of research and the enhancement of over 60 energy efficiency measures (EEMs) for the NELC database regarding information that includes, but is not limited to: EEM exploration and benefits, regulations and codes, energy saving calculations, online resources, and savings payback periods.
- Analyzed homes to deliver free home energy audits to the local community.
- Devised course material with fellow interns for the NELC class offered through Penn State campuses.

West Food District – Student Supervisor (University Park, PA) **Fall 2012 – Present**

- Oversee and manage nearly 200 students employed by West Food District as well as maintain office duties, coordinate special projects and trainings, conduct meetings and interview potential employees.

Penn State Eco-Rep (University Park, PA) **Fall 2011 – Spring 2013**

- Managed and educated Eco-Rep students in their work, projects, and responsibilities.
- Strove to encourage recycling and sustainable living amongst peers and college community.
- A core member in organizing Campus Conservation Nationals (Spring 2013).

LEADERSHIP & ACTIVITIES

Research – Commercial Building Efficiency (Dr. Somayeh Asadi) **Summer 2015**
Energypath – Passive Solar House **Summer 2015**
GREEN Program – Costa Rica **Winter 2014**
Energypath – Energy Efficiency **Summer 2013**

- *President*, NECA Student Chapter
- *Member*, Society of Energy Engineers
- *Member*, Energy Business and Finance Society
- *Former Vice President*, STATERS (Student Taking Action to Encourage Recycling)

Gabrielle Elizabeth Reese

833 West College Ave, State College, PA 16801 • ger5048@gmail.com • (570) 878-3490

Education

***Bachelor of Science, Energy Engineering*; Degree anticipated** **May 2016**
Pennsylvania State University, University Park, State College, PA

Work Experience

Meta Engineering - Intern (Honolulu, Hawaii) Summer 2015

Leadership Experience

- Vice President of NECA's (National Electrical Contractors Association) Pennsylvania student chapter
- Public Relations officer and Secretary for Eco-Action - Penn State's oldest standing environmental organization
- Trainer at the Sierra Student Coalition's SPROG (summer grassroots leadership training program) and member of the Training Committee

Extracurricular Activities

- Participated in CAUSE, a three semester long Penn State program focusing on energy in New Zealand. Traveled to the country summer of 2013 visiting various power plants.
- Member of Central Pennsylvania Community Housing's cooperative for three years.

Skills

- Much experience with cooperative/consensus decision making and conflict mediation
- Effective communication skills with a desire to engage and encourage others to want to do similarly
- Excellent interpersonal skills
- Familiar with Microsoft Excel, Mathematica, CHEMKIN, MATLAB and LaTeX.

HALEY D. BENDIS

316 W. Beaver Avenue Apt. 305 State College, Pennsylvania 16801 • hdb5053@psu.edu • (412) 913-5066

EDUCATION

The Pennsylvania State University 2012-2017
Bachelor of Architectural Engineering University Park, Pennsylvania
A.B.E.T. Accredited
GPA: 2.93

WORK EXPERIENCE

Touching Hearts at Home (Pittsburgh, PA) **May 2014-August 2014**

- Assisted elderly clients in the home to enable their independent living
- Responsible for providing companionship, light housekeeping, meal preparation, medication reminders, and transportation

Kennywood Amusement Park (Pittsburgh, PA) **June 2013- July 2013**

- Sold souvenirs and light-up toys in a gift shop

Carmike Cinemas (Bethal Park, Pennsylvania) **March 2011-August 2012**

- Worked on floor staff selling tickets and concession
- Oversaw the overall cleanliness of theater

Baptist Homes Nursing Home (Mount Lebanon, Pennsylvania) **May 2008-November 2011**

- Volunteered weekly facilitating resident activities Instructed a weekly French class for residents
- Built strong relationships with residents and made individual visits

LEADERSHIP & ACTIVITES

- *Member*, Illumination Engineering Society (IES)
- *Secretary*, The National Electric Contractors Association (NECA)
- *Participant*, Nittany Lights 2014
- *Participant*, Friday Night Lights Out

SKILLS

- Revit
- Google Sketchup
- Hand Drafting
- AGI
- AutoCAD
- Photoshop
- Acrylic Paint

KEVIN CLEMENT

223 West Hamilton Ave. State College, PA 16801 • Kic5220@psu.edu • (585) 208-5896

EDUCATION

Bachelor of Architectural Engineering

The Pennsylvania State University, University Park, PA
Expected Graduation: May 2016
GPA: 3.27
Major GPA: 3.55

WORK EXPERIENCE

Assistant Project Manager Intern (June 2014- July 2014)

Truland Systems, 1900 Oracle Way, Suite 700 Reston, VA 20190

- Worked on-site at a 12 story women's and children's hospital
- Wrote Requests for Information and posted onto current drawings
- Performed take-offs for change orders & material needed to be released
- Completed weekly material audits
- Managed core-drilling

Warehouse Assistant (May 2011- Aug. 2013)

O'Connell Electric, 390 Systems Rd, Rochester, NY 14623

- Assisted in managing the tool inventory
- Organized Material
- Dropped off materials at job sites

LEADERSHIP & ACTIVITES

- *President*, National Electrical Contractors Association Student Chapter 2014-15
- *Placement Officer*, The Student Chapter of the Partnership for Achieving Construction Excellence 2014-15
- *Member*, Student Society of Architectural Engineers 2012-15
- *Member*, THON Merchandise Order Management Committee 2014-15
- *Member*, Boulevard- Community Service and THON Organization 2011-14

EXTRACURRICULAR ACTIVITIES

- 1st Place in the Student Passport Program Competition 2014-15
- 2nd Place in the Green Energy Challenge 2013
- Scholarships from the Penn-Del-Jersey NECA Chapter 2013,14

SKILLS

- Primavera P6
- Timberline
- AutoCAD
- Revit
- Sketchup
- Microsoft Office

JIYE CHOI

421 E Beaver Ave. State College, PA 16801 • jic5738@psu.edu • (814) 777-8157

EDUCATION

The Pennsylvania State University, University Park, PA *Spring 2017*

B.S Degree in Energy Engineering
Minor in Energy Business and Finance

WORK EXPERIENCE

HUB Dining – Student Employee (University Park, PA) *September 2014- Present*

- Started working on campus to meet various people from diverse backgrounds and learn how to manage time effectively by working while studying
- Take economic responsibilities and work to support my family back in Korea

LEADERSHIP & ACTIVITIES

National Electrical Contractors Association – Treasurer *January 2015-Present*

- Attend weekly meetings including managing club money and assist president and vice president

Korean Students for Christ - Welcome Team Member *January 2014-May 2015*

- Organize club members, prepare for the club meeting
- Attending weekly meeting to plan how to welcome people and how to make people comfortable when they come

SKILLS

- Easy-going and well organized professional who is mature and dependable
- Fluent in English and Korean
- Chinese characters rating examination passed

Technical Analysis I: Energy Audit and Benchmarking

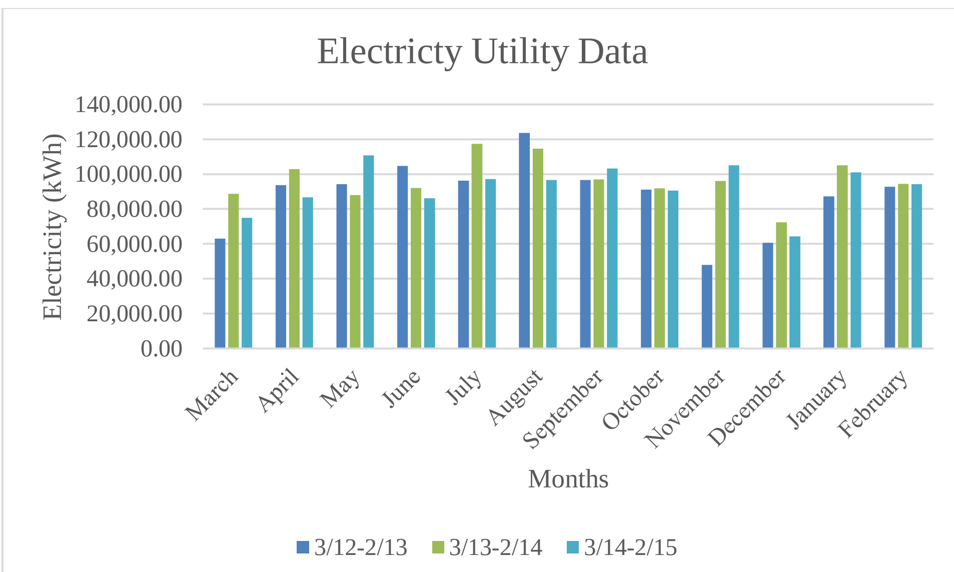
Assessment

We were able to perform an energy audit on the Henning Building thanks to data given to us from Penn State's Office of Physical Plant. The building, like all others on campus, receives high pressure steam through underground piping that comes from both our nearby West Campus Steam Plant and East Campus Steam Plant. The former has long utilized coal to produce this steam, but due to a recent 2013 EPA law, has begun to transition into natural gas whereas the latter has already favored this form to provide peak steam demands.

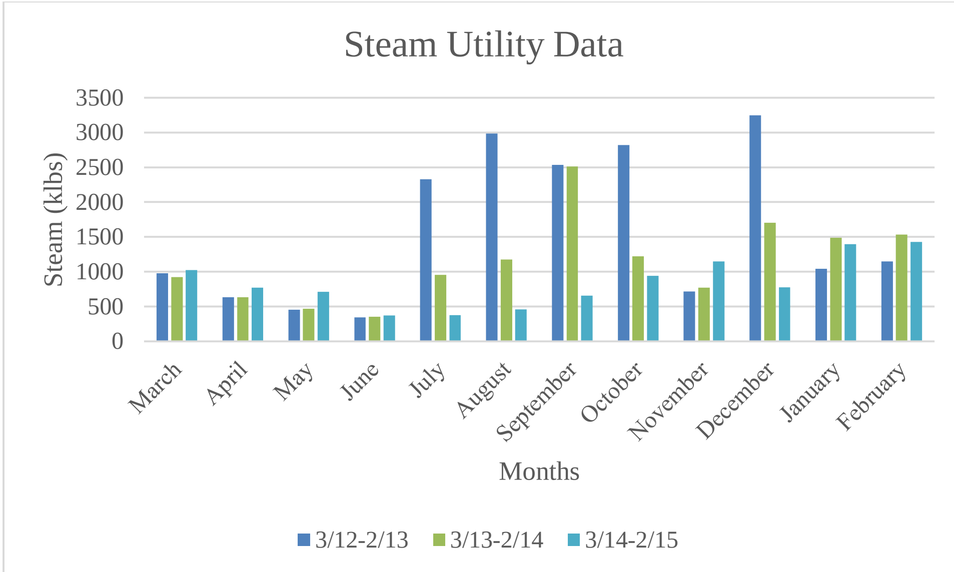
The mechanical equipment voltage varies between 120V and 480V. Over the course of a year, the Henning Building consumes an average of 1,107.5 MWh of electricity.

Energy Usage and Benchmark

Agricultural Sciences, Henning's neighboring Building, has a similar functionality and therefore can serve as a good building to compare. Because none of the buildings are quite the same size though, we compared them on a per square foot basis. We found that the Henning Building used slightly more energy on average.



Graph 1: Electricity Utility Data



Graph 2: Steam Utility Data

Recommendations

General Overview

Given the current nature of the Henning Building and its systems, we hoped to make some key recommendations towards many of the mechanical systems within the building. The building has long been due for some renovations and upgrades, but these dates have been postponed multiple times throughout recent years. This has been done in part due to priorities in surrounding buildings and partly due to the complexity and the required usage of the building.

Our examination through the accessible building did not reveal any glaring concerns in terms of energy loss and gave no grand opportunity for simple, obvious savings beyond lighting. This, coupled with what we heard from those who frequent the building or work within it, confirmed our initial beliefs. This did not come as much of surprise to us, given the need for stable, controlled environments for research and a lack of significant degradation as many of the occupants are not negligent students. If anything, the largest source of preventable energy loss in the building could be attributed to poor conservation habits rather than flaws in the building itself.

Mechanical Systems

The mechanical systems located in the basement were certainly in need of some upgrades. As mentioned previously, the university has been in the works to make some of these changes, but they have not fully materialize for a number of reasons. As of now, the university roughly aims to address Henning around 2020. Many of the surrounding buildings and those with similar functionality are currently in the process of being renovated, limiting flexibility for us in terms of displacing occupants if needed.

During the course of our time researching Henning, the chiller that had been shared with the neighboring Agricultural Sciences Building was being replaced and suited with technology to monitor Henning's individual usage. This eliminated the need for us to delve into a recommendation of our own.

According to code and the specific nature of the Henning Building, the air handler must intake 100% outdoor air. Although this cannot be altered in itself, the fact that there is no heat recovery system in place is a huge source of wasted thermal energy. Due to its age, retrofitting the unit to incorporate a heat recovery system is not recommended over replacing the unit when possible.

A majority of the equipment and units are original to the building and would certainly benefit from an upgrade, but no such solution could be reached without major disruption to the clients and their practices. Standard estimates for such recommendations that this could render the building inaccessible to the occupants for multiple weeks. Although complicated and inconvenient, this could be feasible if the other buildings were not undertaking renovations of their own. With our client's needs, future timeline, preferences, and cost-effectiveness in mind, we do not recommend any mechanical upgrades at this time.

Technical Analysis II: Lighting Retrofit

Objective

To provide an energy efficient and economically feasible lighting upgrade that utilizes LED technologies and lighting controls while abiding by ASHRAE/IES 90.1 and safety regulations.

Assessment

The Henning Building houses offices, study laboratories, and animal research laboratories for the Department of Animal Science and Department of Veterinary and Biological Sciences on Penn State's campus. The majority of the building is illuminated using linear fluorescent fixtures. The dominant lamp type is the fluorescent T8, with T12's and T5's being the minority. The existing lighting also includes a small amount of CFL's as well as T5 and T8 U-tubes. The fixtures are primarily recessed parabolic, with some surface-mounted. Using qualitative and quantitative criteria, the existing lighting conditions can be assessed as poor. There is a color shift issue with the fluorescent lights. The corridors are also dimly lit, which becomes hazardous in an emergency situation.

The building utilizes 120/208V and is fed from the basement electrical room. A 500 kVA 3-phase dry-type transformer is located on the south-western side of the building. The transformer steps the voltage down from 4160V to 120/208V. The following lighting analysis breaks the spaces interior, exterior, and site lighting.

Recommendations

Interior

The focus of the interior lighting retrofit is on laboratories and office spaces. Due to the existing fixtures in the spaces, it was found that retrofit kits would be an affordable replacement for the existing fixtures in halls, office, and conference rooms. The RTLEDR retrofit kit from Lithonia is largely used across the Penn State campuses. Due to its familiarity, it should make for a reliable purchase. Labor time for installation will be decreased as well. This volumetric fixture will cast light farther up the walls. The laboratories require industrial grade lighting. For this reason, Lithonia's 2TLED 2'x4' fixtures will be used. These lighting effects will create a more uniform distribution and create a more spacious setting. In addition to the aesthetic benefits, these fixtures will reduce power up to 56% annually.

Figure 2: 2RTL2R 2'x2' LED Retrofit Kit

Figure 3: 2TLED 2'x4' Industrial Recessed LED

Two 8’x11’ parabolic fluorescent luminous ceiling fixtures light the main entry and lobby of the Henning building. These will be replaced by two 4’x4’ recessed LED fixtures that will be housed in the recessed ceiling that currently hold the existing fluorescents. The current stairwell fixtures will also be replaced with an LED version that use 30% less power.

Our team also proposed to replace the current exit signs with a more efficient LED model that uses less than 30% power.

Exterior

The high pressure sodium exterior fixtures will be changed to LED equivalents. The wall-mounted lights will be replaced by Lithonia’s LED mini wall sconces that use 9% of the power as the existing fixture. Small recessed compact fluorescent fixtures light the entry doors at the top of a set of grand stairs. We recommend replacing the CFL light with an LED light. This will reduce the power by almost half, and the bulbs have a 22 year life expectancy.

Site

The site around the Henning building has 9 high pressure sodium lamp posts that are used around Penn State’s campus. In order to light the site with a more comfortable light as opposed to the yellow light coming from the HPS, we recommend replacing the fixture with the Louis Poulsen LED equivalent.

Controls

In accordance with ASHRAE/IES 90.1, sensors will be placed in the laboratories, offices, and corridors as required. The Henning building does not see high traffic throughout the day. It houses mainly personal spaces in department offices, graduate laboratory studies, and habitats for animals. Many of the occupants of the building spend long hours in their research. If an occupant enters a room, they are likely to be turning the light on for their individual use. For this reason, the best sensor for this building is a vacancy sensor. The WattStopper CS-50 PIR Wall Switch Vacancy Sensor provides automatic shutoff for single-pole lighting control applications in the home. It uses an LED to detect motion and can be set to shut off after 5-30 minutes after a room is empty.

Figure 4: WattStopper CS-50 PIR Wall Switch Vacancy Sensor

The new lighting plans can be found in Appendix A along with the fixture schedule.

Illuminance Levels

This proposal abides by ASHRAE/IES 90.1 and illuminance levels recommended by the IES Handbook, 10th Edition. Below is a table that summarizes the team’s findings and their correlation with the proposed design. The proposed systems were modeled using Revit and ElumTools to ensure that the required illuminance levels were achieved.

Average Illuminance Levels (fc)			
Space	IES	Actual	Design
Labs	50	76	73
Offices	30	30	33
Corridor	5	4.2	22
Stairwell	5	8	8

Table 1: Average Illuminance Levels (fc)

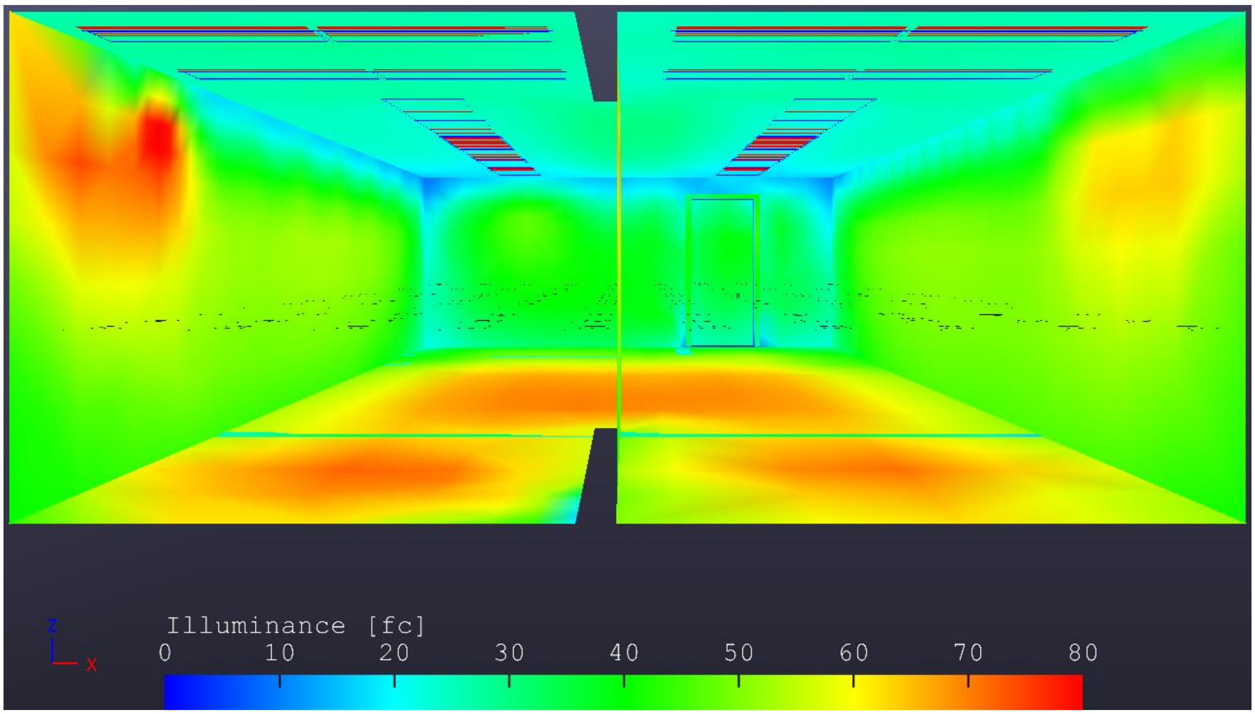


Figure 5: Psuedocolor of Typical Lab

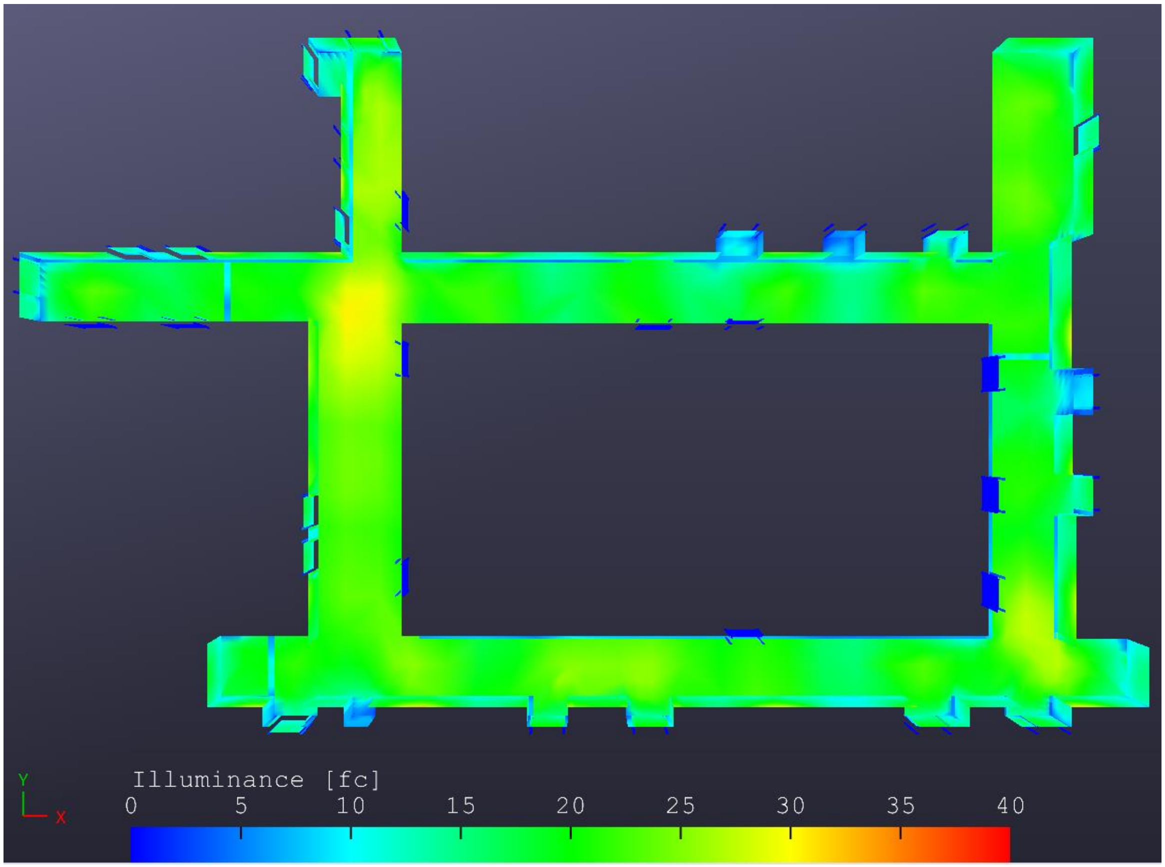


Figure 6: Psuedocolor of Corridor

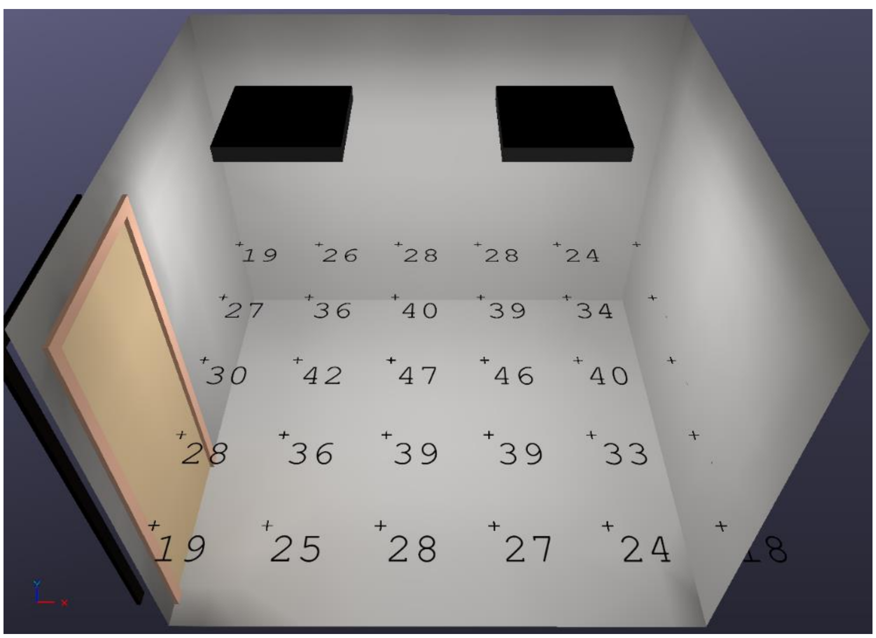


Figure 7: Elumtools Rendering of Office Daylighting

The interior of the Henning Building does not receive much daylight. There are few windows in the halls, and the windows in offices and labs have a drop ceiling that cuts off daylight and doesn't allow much natural light inside. Because of this, we would not recommend harnessing available daylight. However, the recessed fixtures can be controlled by zones, so if enough natural light enters the room, the occupant has control.

Recycling

The majority of existing lighting in the building consists of fluorescent lamps. Fluorescent lamps contain small amounts of mercury that can be exposed to the environment when broken. To avoid the release of mercury, the lamps need to be recycled. The borough of State College has a recycling center that accepts incandescent and LED lamp types. CFL lamps can be recycled at Lowe's or Home Depot, both stores are located within 5 miles of the building. The fluorescent tube lamps types however must be recycled at a special materials drop off location. This drop-off location is at the Hite Company, located along the Benner Pike in State College, PA, 7 miles from the Henning Building. The "revitalized lamp recycling program" offers DISPOSALPAK recycling kits that are available at this location. Using a bulk method, lamp recycling will be based on a linear foot unit and will also include transportation and certificate.

The WattStopper has a sustainable packaging delivery for vacancy sensors that uses recycled packaging and boxes their product specifically designed to use 37% less space for storage and transportation.

Energy Savings

The lighting upgrade will have a total cost of $264,095.88 using the energy rate of 0.25 $/kWh, the energy savings were calculated based on the proposed lighting system. By upgrading the existing system to LED, the kilowatt hours saved per year will be 128,533. In 5 years, the upgrade will save $160,666.00. These estimates are shown in **Figure 18** in Appendix A. With these savings, the payback period for the lighting upgrade will be slightly over 8 years. The cost benefits from upgrading the system to LED after one year are enough to prove that this is a feasible proposal.

Critical Load Analysis and Micro grid Concept

1.1 Introduction

Our team was tasked to design a reliant, resilient and responsive system for our client to provide back-up power for the critical load of the Henning building. Through a structural, mechanical and electrical analysis, we found that the building contains labs for mammalian research involving mice housed in life support units which require constant power in order for various ongoing animal studies to remain online. The power generation system we have designed incorporates a solar array which creates an autonomously operating micro grid. To mitigate the issues involved with the intermittency of solar irradiation, batteries will be coupled with the array to ensure that power is constantly supplied. This system is being installed in conjunction with a back-up supply that is currently available to the Henning building provided by an off-site diesel generator.

1.2 Critical Load Analysis and Concept

Our client requires a continuous power supply for the critical loads of Henning Building to be met in the case of a power outage. The Critical loads are divided into two categories; Animal Life support and Emergency systems. The animal housing units, in which mice are held, require a steady supply of power that must not fail in the case of a main power loss to operate the HVAC system that provides the living environment suitable for animal survival. The emergency systems which include exit signage, fire alarms, smoke detection, sprinkler system and critical lighting fixtures also require power in the case of a power failure. The two components of the critical load are can also be derived into mechanical and life safety sectors that utilize a three phase alternating current power system.

This three phase system, with a power factor of 0.9, requires 25 kVA for the mechanical equipment and 4.6 kVA for life safety. A calculation for true power reveals 46.1 kW for the load. Penn State's standards require that the system be able to provide back-up power for a minimum of 72 hours. Currently, the Henning Building's critical load is provided by a Diesel generator that is not located on site. Thus, our system will provide back-up power in addition to that currently in place. A solar array on the roof of the building will generate power when our Solar resource, the Sun, is available for energy production. Any power produced by the array will be sent back to the grid during normal power conditions and will supply Henning directly in the case of an outage. In the case of a power outage at night when there is no solar irradiance the critical load will be held by the solar ray battery system and diesel generator. In the event of a power outage during the day, however, the array which is rated at 53.25 kW, is able to supply power to the load. To compensate for intermittencies in our solar energy production, batteries are able to be discharged to the critical load when needed.

1.3 Solar Array

1.3.1 Location

The images below show the roof layout where the three arrays will be placed. The north, south and east sides of the building were chosen as the most ideal locations for the arrays due to their maximal exposure to solar irradiance and lack of presence of mechanical and HVAC equipment. The locations for each array can be seen in Figure 8.

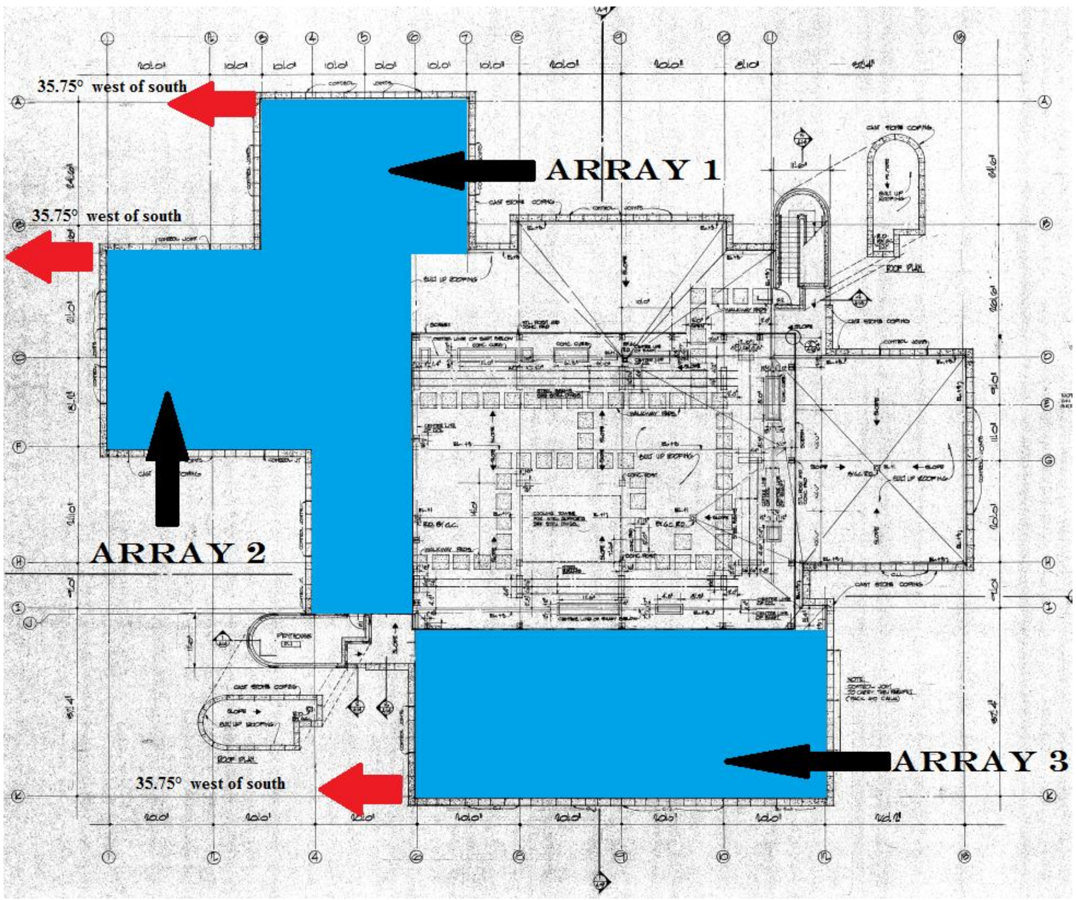


Figure 8: Roof plan including proposed array locations and orientations

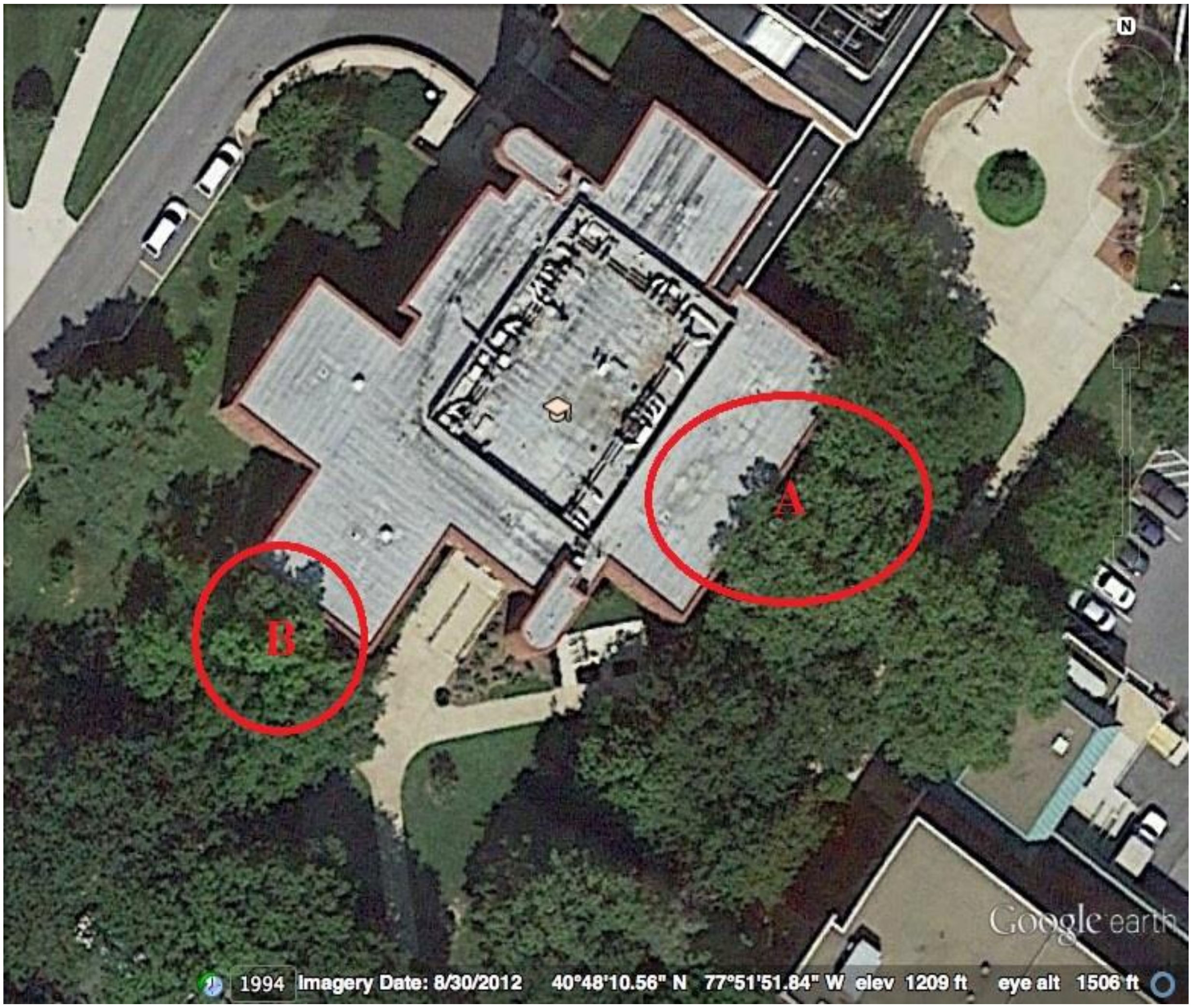


Figure 9: Satellite image of the Henning Building with areas of shading concern.

Locations where shading could be an issue are highlighted. It appears from looking at **Figure 9** that the shading in location (A) will be more significant than (B). To obtain maximum exposure, a solar system should ideally face due south in the northern hemisphere. Our design restrictions of minimal space lead us to orient them in a way which reduces the overall current received through each inverter. This is due to the current constraint being the dominating factor in sizing the inverter for the system. Each array shown in **Figure 8** is oriented 25.75° west of south (the azimuth angle).

1.3.2 Design

Below are the details for each array. We chose to orient arrays in the following row by column orientations. We chose the Westinghouse WTW-250-1-DC4-0-B model for our array, each panel costing $375.

Array 1: 3 x 8
Array 2: 5 x 17
Array 3: 8 x 13

213 panels
Voltage of each panel = 30.9 V
Current of each panel = 8.1 A
Power of each panel = 0.25 kW
Total Power = 53.25 kW

	Array 1	Array 2	Array 3
Number Panels	24	85	104
Power (kW)	6	21.25	26
Voltage (V)	30.9	525.3	401.7
Current (A)	24.3	40.5	64.8

Figure 10: Array data

1.3.3 Mounting

The ballasted method will be used to mount the array as opposed to a drill technique saving costs**. Figure 11** below gives a visual representation of the ballasted racking method. Ballast mounts rely solely on the weight of the array, racking system and additional material, such as concrete pavers to hold the array to the roof. The ballasted system is limited to a maximum angle of 20° to minimize wind uplift forces. This system does not eliminate the need for working with a roofing contractor, but can significantly reduce the coordination required between the roofer and the PV installer. Another benefit of the ballasted system is that is can withstand 120 mph winds. The system still requires an assessment from a structural engineer to ensure safe roof loading.

Figure 11: Ballasted Racking

1.4 Batteries and Inverters

We plan to ensure constant power is being delivered to our load when the array is providing power and have coupled lead acid batteries into the system that are able to discharge and provide power when there is not enough sun during intermittent periods. There are 139 raining days per year in State college, but we want to estimate the shading time per hour during the daytime. From our calculation, that is about 23 minutes per hour during the daytime that our panel won’t function at its rated optimal efficiency due to the weather. The efficiency of our panels under the cloudy condition is about 5% to 15%. We estimated it as 10% for our panels. When our panels cannot function efficiently to meet our critical load, we need power from our back up battery. The battery that we chose is EnerSys Genesis Pure Lead XE95 0790-6001. We chose it because it is a lead acid battery designed for renewable energy usage. The constant discharge performance of this battery for 30 minutes is 1.494kW and the amount of power that it should make up to meet the critical load under the cloudy condition is 40.68 kW. That gives us the result that 28 EnerSys Genesis Pure Lead XE95 are needed to meet our critical load when the panels cannot function efficiently due to the weather conditions. The total cost for these batteries comes out to $10,780.

Array 1 in our system requires one inverter. We chose the ABB (Power-One) PVI-6000-OUTD series inverter rated at 6.244 kW. Array 2 requires three inverters and we chose the SMA America SB7000TL-US-22 inverter each rated at 7.288 kW. Array 3 requires 3 inverters as well and we chose the SMA America SB90000TL-US inverter each rated at 9.242 kW.

1.5 Cost

The following table totals the cost for all the components of our system.

Description	**Quantity**	**Unit**	**Cost ($)**	**Total**
Solar Panels	213	Ea.	375	79,875
ABB (Power-One) PVI-6000-OUTD Series	1	Ea.	2,000	2,000
SMA SB7000TL-US-22	3	Ea.	2,800	8,400
SMA SB9000TL-US	3	Ea.	2,918	8,754
Combiner Box	7	Ea.	85	595
Disconnect	7	Ea.	60	542
DC Lightning Arrestor	7	Ea.	40	280
AC Lightning Arrestor	7	Ea.	45	315
Ballasted Flat Roof Racking	213	Ea.	55.63	11,849.19
Blocks	852	Ea.	1.25	1,065
100 ft. MC4 Cables	50	Ea.	70	3,500
Battery 12V 95 Ah	28	Ea.	385	10,780
			Labor Total	$28,275.30
			PV Array Total	$156,108.49

Table 2: Component Cost

Initial Investment ($)	156108
Life Span of Analysis (n) (years)	20
Down Payment (fraction)	0
Interest Rate (i) (fraction)	0.055
Fuel Savings (FS) ($)	14370.7865
Market Discount Rate (d) (fraction)	0.07
Fuel Inflation Rate (i of FS) (fraction)	0.06
Maintenance/Insurance/Parasitic Annual Cost (fraction)	0.01
Resale Value (excluding PW) (fraction)	0.35
Length (m)	20.1168
Width (m)	18.5928
Size of Array (m^2)	374.027639
Fire Code (fraction)	0.666
Panels	213
Panels taken away due HVAC units	6
Panels (Revised)	207
Power (250W pannels) (kW)	53.25
Power (kWh)	57483.146
Cost of Electricity per kWh ($)	0.25
Fuel Savings	
Solar Fraction (fraction)	0.048832888
PWF (n,i,d) (Eq. 10.9)	11.95038248
Down Payment ($)	0
Loan ($)	156108

Table 3: Given Information

Life Span of Analysis (n) (years)	Loan Payment (Eq. 10.10) (Loan/PWF) ($)	Interest Paid (Eq. 10.11/10.12) ($)	Loan Remaining (Principle Balance) (Eq. 10.11/10.12) ($)	Fuel Savings ($)	Operating Cost (Maintenance/Insurance/Parasitic Annual Cost) ($)	Solar Savings ($)	Present Worth of Solar Savings ($)
0			156108.00			0	0.00
1	13063.01	8585.94	151630.93	14370.79	1561.08	-253.31	-236.73
2	13063.01	8339.70	146907.62	15233.03	1576.69	593.33	518.24
3	13063.01	8079.92	141924.52	16147.02	1592.46	1491.55	1217.55
4	13063.01	7805.85	136667.36	17115.84	1608.38	2444.44	1864.85
5	13063.01	7516.70	131121.05	18142.79	1624.47	3455.31	2463.59
6	13063.01	7211.66	125269.69	19231.35	1640.71	4527.63	3016.95
7	13063.01	6889.83	119096.51	20385.24	1657.12	5665.10	3527.94
8	13063.01	6550.31	112583.81	21608.35	1673.69	6871.65	3999.36
9	13063.01	6192.11	105712.91	22904.85	1690.43	8151.41	4433.83
10	13063.01	5814.21	98464.10	24279.14	1707.33	9508.80	4833.79
11	13063.01	5415.53	90816.62	25735.89	1724.40	10948.47	5201.54
12	13063.01	4994.91	82748.52	27280.04	1741.65	12475.38	5539.22
13	13063.01	4551.17	74236.67	28916.85	1759.06	14094.77	5848.83
14	13063.01	4083.02	65256.68	30651.86	1776.65	15812.19	6132.24
15	13063.01	3589.12	55782.78	32490.97	1794.42	17633.53	6391.20
16	13063.01	3068.05	45787.82	34440.43	1812.37	19565.05	6627.36
17	13063.01	2518.33	35243.14	36506.85	1830.49	21613.35	6842.23
18	13063.01	1938.37	24118.50	38697.26	1848.79	23785.46	7037.26
19	13063.01	1326.52	12382.00	41019.10	1867.28	26088.80	7213.77
20	13063.01	681.01	0.00	43480.24	1885.95	28531.28	7373.02

Table 4: Cost Estimate

Our system provides additional back-up power that is resilient and not reliant on the grid. A solar array provides the Henning building with power that can be fed back to the grid providing the potential for an eventual return on investment for Penn State. It can be seen by looking at **Table 4** that after one year the present worth of solar savings for Penn State increases to \$518.24 and after twenty years is up to \$7,373.02. Thus, Penn State will reach their payback period in 20 years. Another benefit to this system is having the option to power the critical loads by a renewable resource as opposed to the current diesel generator powered back-up system. This entails the possibility to burn less fossil fuels with the addition of our system.

Schematic Estimate, Schedule, and Finance Plan

Cost Estimate

Our team conducted a thorough estimate to determine the costs for the lighting retrofit, photovoltaic array, and additional costs for the Henning Building retrofit. The total project cost is $527,437.16. This total includes 6% sales tax on the material, 15% for overhead and profit, and 2% contingency. The summary estimate of the Henning Building can be seen in **Table 5.**

Table 5: Project Estimate Summary

Henning Project Estimate	
Lighting Subtotal	$264,095.88
PV Array Subtotal	$169,525.50
Project Subtotal	$389,992.38
Tax (6%)	$20,100.14
O & P (15%)	$65,043.21
Contingency (2%)	$8,672.43
Project Total	**$527,437.16**

Lighting Estimate

The lighting retrofit estimate was determined through the use of quotes for the fixtures and the use of electricians at a rate of $60.00. This rate was based off of RS Means. This labor rate could be reduced through the use of apprentices on the job, but for this estimate the standard electrician labor rate was used to be conservative. The unit labor cost in **Table 6 (Detailed Cost Estimate Table)** includes the cost to remove the existing fixtures and install the new fixture.

Photovoltaic Array

The photovoltaic array estimate was determined through the use of quotes for the major materials and the use of electricians at a rate of $60.00. This rate was based off of RS Means. This labor rate could be reduced through the use of apprentices on the job, but for this estimate the standard electrician labor rate was used to be conservative.

Table 6: Detailed Cost Estimate

Description	Quantity	Unit	Unit Material Cost ($/Unit)	Total Material Cost ($)	Unit Labor Cost ($)	Total Labor Cost ($)	Total Material & Labor Cost ($)
Lighting Retrofit Estimate							
2 x 4 LED Retrofit Kit	233	Ea.	$ 193.69	$ 45,129.77	$ 30.00	$ 6,990.00	$ 52,119.77
2 x 2 LED Retrofit Kit	49	Ea.	$ 188.43	$ 9,233.07	$ 30.00	$ 1,470.00	$ 10,703.07
2 x 4 LED	342	Ea.	$ 214.74	$ 73,441.08	$ 90.00	$ 30,780.00	$ 104,221.08
1 x 4 LED	76	Ea.	$ 198.95	$ 15,120.20	$ 90.00	$ 6,840.00	$ 21,960.20
1 x 4 Industrial LED	159	Ea.	$ 272.64	$ 43,349.76	$ 90.00	$ 14,310.00	$ 57,659.76
Display	3	Ea.	$ 76.00	$ 228.00	$ 60.00	$ 180.00	$ 408.00
1 x 1 LED	2	Ea.	$ 311.58	$ 623.16	$ 60.00	$ 120.00	$ 743.16
Luminous Ceiling	2	Ea.	$ 2,605.27	$ 5,210.54	$ 90.00	$ 180.00	$ 5,390.54
Stairwell	18	Ea.	$ 272.64	$ 4,907.52	$ 90.00	$ 1,620.00	$ 6,527.52
Exit Signs	13	Ea.	$ 73.90	$ 960.70	$ 60.00	$ 780.00	$ 1,740.70
Lamp post	1	Ea.	$ 1,410.53	$ 1,410.53	$ 240.00	$ 240.00	$ 1,650.53
Wall Pack	3	Ea.	$ 224.88	$ 674.64	$ 60.00	$ 180.00	$ 854.64
Square	3	Ea.	$ 8.97	$ 26.91	$ 30.00	$ 90.00	$ 116.91
			Material Subtotal	*$ 200,315.88*	*Labor Subtotal*	*$ 63,780.00*	
					Lighting Subtotal		**$ 264,095.88**
Photovoltaic Array Estimate							
Solar Panels	213	Ea.	$ 375.00	$ 79,875.00	$ 60.00	$ 12,780.00	$ 92,655.00
ABB (Power-One) PVI-6000-OUTD Series	1	Ea.	$ 2,000.00	$ 2,000.00	$ 540.00	$ 540.00	$ 2,540.00
SMA SB7000TL-US-22	3	Ea.	$ 2,800.00	$ 8,400.00	$ 540.00	$ 1,620.00	$ 10,020.00
SMA SB9000TL-US	3	Ea.	$ 2,918.00	$ 8,754.00	$ 540.00	$ 1,620.00	$ 10,374.00
Combiner Box	7	Ea.	$ 85.00	$ 595.00	$ 360.00	$ 2,520.00	$ 3,115.00
Disconnect	7	Ea.	$ 60.00	$ 420.00	$ 240.00	$ 1,680.00	$ 2,100.00
DC Lightning Arrestor	7	Ea.	$ 40.00	$ 280.00	$ 180.00	$ 1,260.00	$ 1,540.00
AC Lightning Arrestor	7	Ea.	$ 45.00	$ 315.00	$ 180.00	$ 1,260.00	$ 1,575.00
Ballasted Flat Roof Racking	53250	per Watt	$ 0.25	$ 13,312.50	$ 0.10	$ 5,325.00	$ 18,637.50
Blocks	852	Ea.	$ 1.25	$ 1,065.00	$ 2.00	$ 1,704.00	$ 2,769.00
100 ft MC4 Cables	50	Ea.	$ 70.00	$ 3,500.00	$ 15.00	$ 750.00	$ 4,250.00
Battery 12V 95Ah	42	Ea.	$ 385.00	$ 16,170.00	$ 90.00	$ 3,780.00	$ 19,950.00
			Material Subtotal	*$ 134,686.50*	*Labor Subtotal*	*$ 34,839.00*	
					PV Array Subtotal		**$ 169,525.50**
					Project Subtotal		**$ 433,621.38**
					Tax (6%)		$ 20,100.14
					O & P (15%)		$ 65,043.21
					Contingency (2%)		$ 8,672.43
					Project Total		**$ 527,437.16**

Schedule

The construction project schedule will be during the summer of 2015. The construction will start on May 18th and conclude on July 31st. This date was chosen in order to satisfy our client, Pennsylvania State University. They wanted the construction to occur during the summer because of the greatly reduced student and vehicle traffic around the building. The Henning Building is also used less during the summer. The Henning Building conveniently has a loading dock off of a road that is only used by the Penn State employees of the Office of the Physical Plant. A simplified site plan can be seen in **Figure 12.** The main material and equipment storage will be located in the blue area because there is less traffic from pedestrians. All solar equipment will be lifted from the northwest side of the building, but will only be fenced off during lifting to keep the road to the loading dock available to Penn State employees. Therefore, it has not been shown in this site plan since it will only be for short periods of time in the summer.

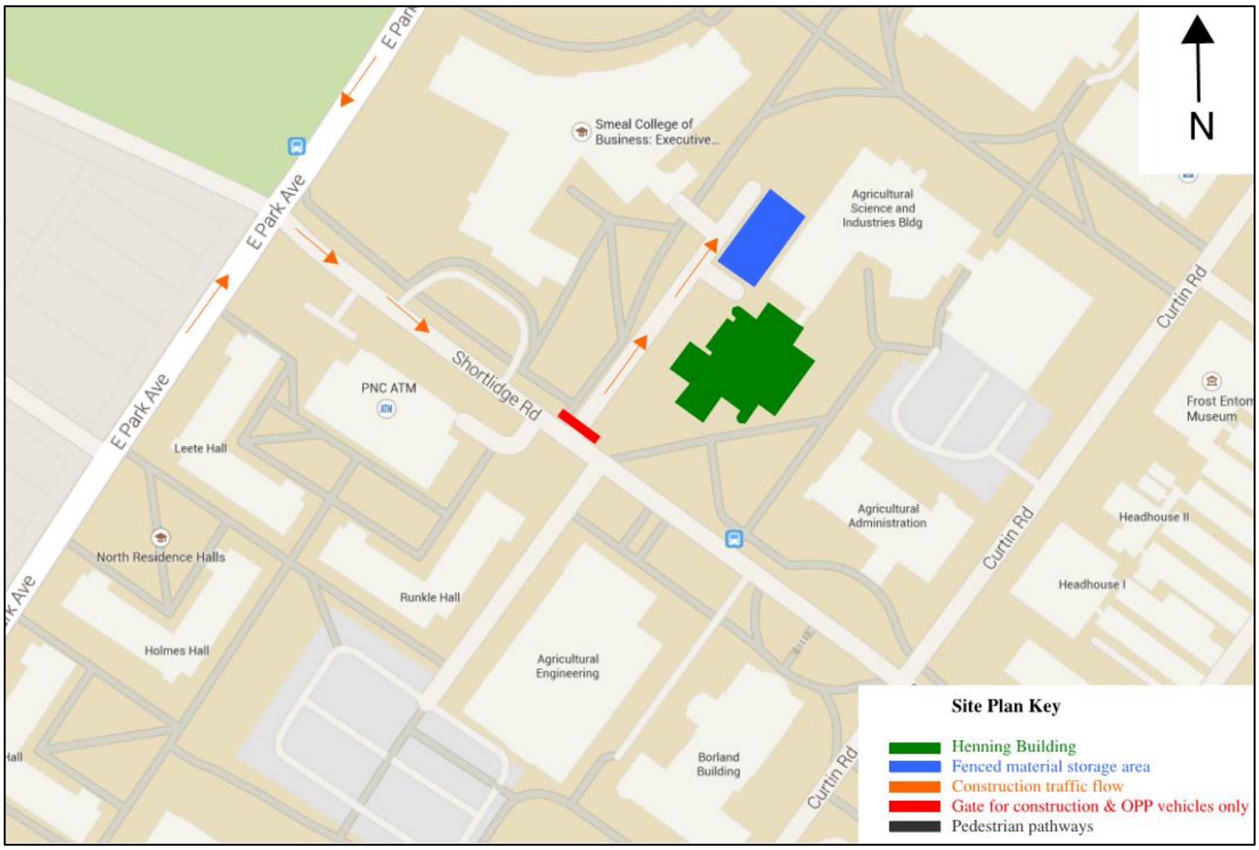


Figure 12: Site Plan

Lighting Retrofit

The lighting retrofit will take 46 days and will begin on May 11th. The retrofit will be completed by 4 electricians. The lighting retrofit will be sequenced by floor and into four sections per floor. This was done in order to keep the building almost fully operational throughout the entire construction process. The sequencing plan of a floor can be seen in **Figure 13**. The sequence per floor will be in a clockwise motion, starting from the shaded blue area and finishing with the shaded green area. The sections were strategically chosen to allow the use of the spaces that are not being renovated. Also, safety is very important for both the construction workers and occupants of the building. Therefore, it is essential that one elevator and staircase is not under renovation, while the other one is. The blue and red shaded sections each contain an elevator and staircase. The lab renovations are to be done during the summer, but the Animal Sciences Department did not provide information about details of when certain labs could be renovated over the summer. Therefore, it would require greater coordination with the Animal Science Department of when each individual lab could be retrofitted. Since, this detailed information was not provided, it was assumed that the retrofit could begin on the ground floor and finish on the third floor.

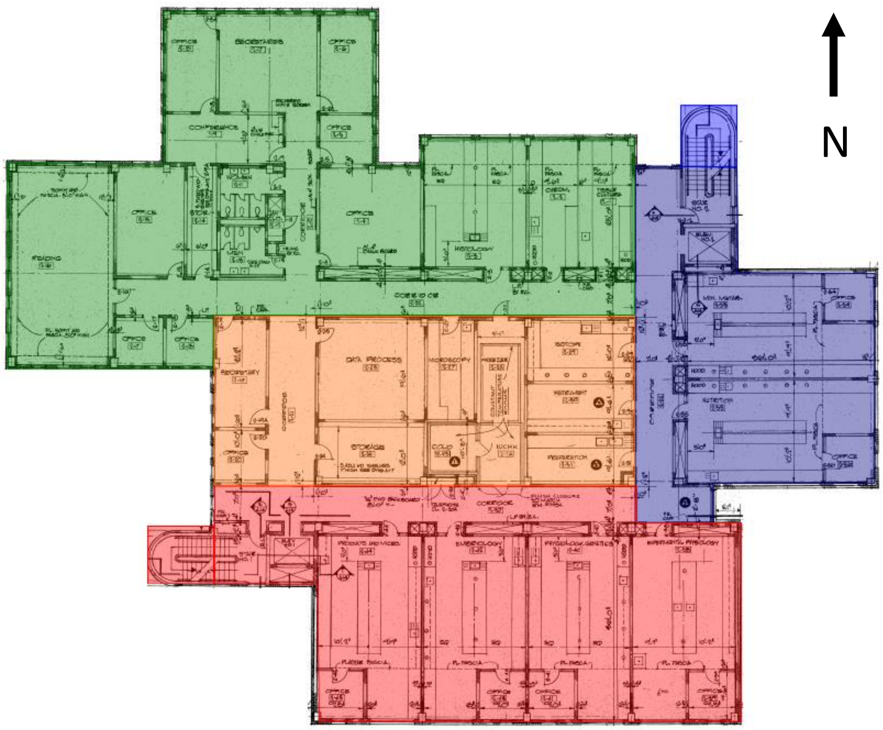


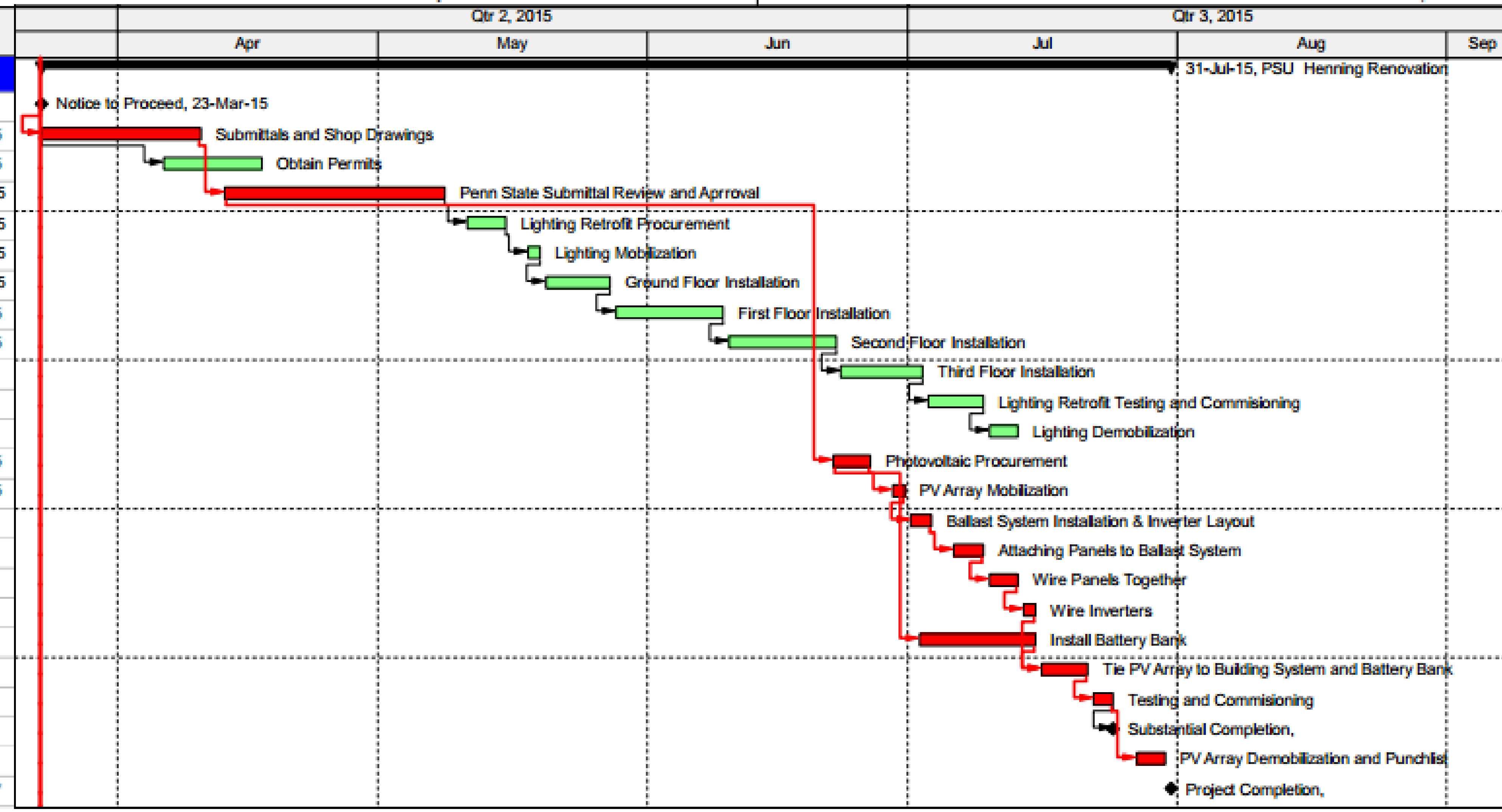
Figure 13: Sequencing per Floor

Photovoltaic Array

The photovoltaic array installation will take a total of 22 days utilizing 4 electricians. The photovoltaic procurement will not start until June 22, 2015 and last a total of 5 days. This was scheduled to have the PV array finish after the lighting retrofit, which will place the PV array installation on the critical path. It is important for the Henning Building to be as energy efficient as possible prior to the PV array going online. This will allow the PV array to power more devices and fixtures. This portion of the project will come to a conclusion on July 27, 2015.

Henning Renovation	Classic Schedule Layout	20-Apr-15 11:46

Activity ID	Activity Name	Original Duration	Start	Finish
	PSU Henning Renovation	94	23-Mar-15	31-Jul-15
A1000	Notice to Proceed	0	23-Mar-15	
A1020	Submittals and Shop Drawings	15	23-Mar-15	10-Apr-15
A1025	Obtain Permits	10	06-Apr-15	17-Apr-15
A1030	Penn State Submittal Review and Aprroval	20	13-Apr-15	08-May-15
A1040	Lighting Retrofit Procurement	5	11-May-15	15-May-15
A1045	Lighting Mobilization	2	18-May-15	19-May-15
A1050	Ground Floor Installation	6	20-May-15	27-May-15
A1060	First Floor Installation	9	28-May-15	09-Jun-15
A1070	Second Floor Installation	9	10-Jun-15	22-Jun-15
A1080	Third Floor Installation	8	23-Jun-15	02-Jul-15
A1090	Lighting Retrofit Testing and Commisioning	5	03-Jul-15	09-Jul-15
A1095	Lighting Demobilization	2	10-Jul-15	13-Jul-15
A1100	Photovoltaic Procurement	5	22-Jun-15	26-Jun-15
A1105	PV Array Mobilization	2	29-Jun-15	30-Jun-15
A1110	Ballast System Installation & Inverter Layout	3	01-Jul-15	03-Jul-15
A1120	Attaching Panels to Ballast System	4	06-Jul-15	09-Jul-15
A1130	Wire Panels Together	2	10-Jul-15	13-Jul-15
A1140	Wire Inverters	2	14-Jul-15	15-Jul-15
A1145	Install Battery Bank	10	02-Jul-15	15-Jul-15
A1150	Tie PV Array to Building System and Battery Bar	4	16-Jul-15	21-Jul-15
A1160	Testing and Commisioning	3	22-Jul-15	24-Jul-15
A1165	Substantial Completion	0		24-Jul-15
A1170	PV Array Demobilization and Punchlist	4	27-Jul-15	30-Jul-15
A1180	Project Completion	0		31-Jul-15*



Actual Level of Effort | Remaining Work | Milestone
Actual Work | Critical Remaining Work | summary

Page 1 of 1

TASK filter: All Activities

Figure 14: Henning Building CPM Schedule

Finance Plan

The financing of the project was determined by consulting Penn State's Office of the Physical Plant (OPP). Penn State uses the same financing plan for all projects, with a loan period of 10 years at 5.5% interest, and no down payment on the project. The required payback period of 10 years should be met in order to follow through with any project. The Henning Building project will have a total cost of $527,437 and will have an annual savings of $46,992 annually. These values were used along with the financing values from OPP to create a cash flow for the project. Cash flows were created for two scenarios: 1) If the system was not installed, and 2) If the system was installed. The costs will be brought back to present value in order to show the costs in "today's dollars".

Incentives were not an option for any portion of the energy retrofit. The Pennsylvania State University is a state institution and does not apply for any incentives or rebates. **Table 7** shows the cash flow if the Henning Building continues with the existing systems in place. Their annual costs will not be reduced by $46,992 per year in electricity and after 10 years, these costs will have a net present value of -$401,200. **Table 8** shows the 10 year cash flow if Penn State installs the proposed systems to the Henning Building. Their annual energy costs will be reduced by $46,992, but there will be annual loan payments of -$55,644. After the end of the 10-year period, these loan payments will have a net present value of -$419,428. The costs of the loan payments are more than continuing to pay the otherwise saved $46,504 in electricity. This shows the project would not be financially viable within 10 years. However, the major priority of this project is to provide resilient power for critical spaces. This proposed project does and would be financially feasible if the cash flow was completed over 12 years. The cash flow for the cash flow over a 12 year period can be seen in **Table 9** and **Table 10.** When comparing the net present value from **Table 9** and **Table 10**, it is evident that the proposed system is the correct financial decision and will provide resilient power to the lab spaces.

Year	Electricity Cost	Present Value
0	$ (46,992.00)	$ (46,992.00)
1	$ (46,992.00)	$ (44,542.18)
2	$ (46,992.00)	$ (42,220.08)
3	$ (46,992.00)	$ (40,019.03)
4	$ (46,992.00)	$ (37,932.73)
5	$ (46,992.00)	$ (35,955.19)
6	$ (46,992.00)	$ (34,080.75)
7	$ (46,992.00)	$ (32,304.03)
8	$ (46,992.00)	$ (30,619.93)
9	$ (46,992.00)	$ (29,023.63)
10	$ (46,992.00)	$ (27,510.55)
	NPV	$ (401,200.11)

Table 7: Cash Flow of Existing Conditions

Year	Loan Payment	Present Value
0		$ -
1	$ (55,644.62)	$ (52,743.72)
2	$ (55,644.62)	$ (49,994.04)
3	$ (55,644.62)	$ (47,387.72)
4	$ (55,644.62)	$ (44,917.27)
5	$ (55,644.62)	$ (42,575.61)
6	$ (55,644.62)	$ (40,356.03)
7	$ (55,644.62)	$ (38,252.16)
8	$ (55,644.62)	$ (36,257.97)
9	$ (55,644.62)	$ (34,367.75)
10	$ (55,644.62)	$ (32,576.06)
	NPV	$ (419,428.32)

Table 8: Cash Flow of Proposed System

Year	Electricity Cost	Present Value
0	$ (46,992.00)	$ (46,992.00)
1	$ (46,992.00)	$ (44,542.18)
2	$ (46,992.00)	$ (42,220.08)
3	$ (46,992.00)	$ (40,019.03)
4	$ (46,992.00)	$ (37,932.73)
5	$ (46,992.00)	$ (35,955.19)
6	$ (46,992.00)	$ (34,080.75)
7	$ (46,992.00)	$ (32,304.03)
8	$ (46,992.00)	$ (30,619.93)
9	$ (46,992.00)	$ (29,023.63)
10	$ (46,992.00)	$ (27,510.55)
11	$ (46,992.00)	$ (26,076.35)
12	$ (46,992.00)	$ (24,716.92)
	NPV	$ (451,993.39)

Table 9: Cash Flow of Existing Conditions

Year	Loan Payment	Present Value
0		$ -
1	$ 43,953.08	$ 41,661.69
2	$ 43,953.08	$ 39,489.75
3	$ 43,953.08	$ 37,431.04
4	$ 43,953.08	$ 35,479.66
5	$ 43,953.08	$ 33,630.01
6	$ 43,953.08	$ 31,876.79
7	$ 43,953.08	$ 30,214.97
8	$ 43,953.08	$ 28,639.78
9	$ 43,953.08	$ 27,146.71
10	$ 43,953.08	$ 25,731.48
11	$ 43,953.08	$ 24,390.03
12	$ 43,953.08	$ 23,118.51
	NPV	$ 378,810.40

Table 10: Cash Flow of Proposed System

Energy Awareness and Business Development

Integration

With our goal being to increase energy awareness amongst the Penn State and State College community, we chose to take a very active approach and target those who would be most willing to learn about the conservation of energy and its importance. Tackling a student body of over 40,000 was of course a daunting task, so we chose to channel our focus specifically towards East Halls, Penn State's largest residence hall complex at University Park boating 14 dormitories for first-year students.

While we scaled down our target audience, East Halls still is the home to roughly 4,000 students throughout the school year. In order to reach as many students as possible, we chose to work with a first-year exclusive student organization called Eco-Reps. The Eco-Reps are strategically placed throughout all of the dorm halls with a goal to create a culture of sustainability at Penn State. These students work through the university with a strong focus in waste reduction and recycling in the fall and energy conservation in the spring.

Innovation and Program Design

We decided to go for the "less is more" approach and make energy simple for the average student. Penn State has long since used the all-freshman residence area to implement sustainable features as the students tend to be more accepting of change in that environment. We wanted to capture that innocence and willingness to learn in our new audience and educate them before they took poor habits with them into their respective housing arraignments next year.

Our goal was to bring energy to life and allow students to better understand how their actions contribute to our overall cause. We accomplished this in many ways during our tabling sessions, such as:

> Handing out informational leaflets – We felt that this was necessary to capture the attention of as many individuals as possible. By handing out leaflets to passerby students, we optimized our time by allowing students to take information with them for later reference, while also giving them full opportunity to personally connect and discuss energy. We created three leaflet designs: two promoting events and one recruiting for our student chapter. The two events that were highlighted were Campus Conservation Nationals (CCN) and Earth Week at Penn State, as can be seen here.
>
> "What is Energy?" Display – We displayed two identical lamps at our table, one containing an LED bulb and the other an incandescent bulb. Students who approached the table were verbally asked questions regarding the lights and their respective efficiencies. Using a Kill-A-Watt meter and a power strip, we demonstrated how the

lamps compared in energy consumption and went on to educate them about "vampire energy".

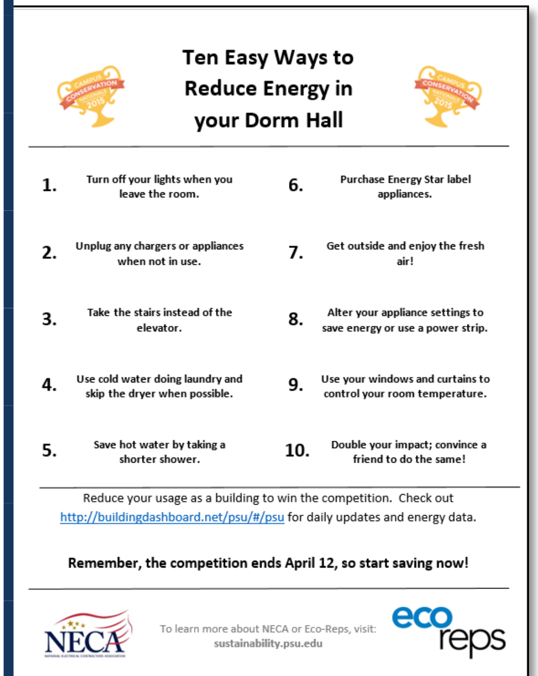
Survey and Picture Pledges – To gain feedback from our participants, we developed a short survey for persons to take via laptop at our table. If they were willing after, we decided to recreate a successful Eco-Rep past-program by encouraging students to pledge what they would do to conserve energy. We had a pair of dry-erase boards and a camera to later display all of the commitments. Students were rewarded for participating with assorted candies.

Eco-Rep Collaboration – Not only was it require that we work with an existing program, but this was a great way to further promote our respective clubs and maximize our presence among freshman students. Some appeared more comfortable approaching our table when help was present from the assisting organization.

For the third consecutive year, the Eco-Reps spearheaded Penn State's participation in Campus Conservation Nationals, while additionally creating a friendly, smaller competition between the 14 buildings within East Halls. To promote awareness and educate students on ways to best save energy, we created a flyer which highlighted ten ways to conserve energy within their dormitory. These were then distributed to students throughout the day and discussed their dorm's progress in the challenge with those who were willing to take the time.

As for Earth Week, Penn State offers many great opportunities for students to learn about sustainable living and green practices. We wanted to promote all of the other clubs that participate in the week's festivities as well as the Sustainability Institute, which is a pivotal part of hosting all events and supporting sustainable initiatives.

Talking about these events led to a great opportunity to spread the word about NECA and recruit for the next year. We discussed the process of how the Green Energy Challenge works, Penn State's past success within the club, and our vision towards the Henning Building. Many of the students passing through had not previously heard of our student chapter, but were happy to learn about our mission and participation in the Green Energy Challenge.



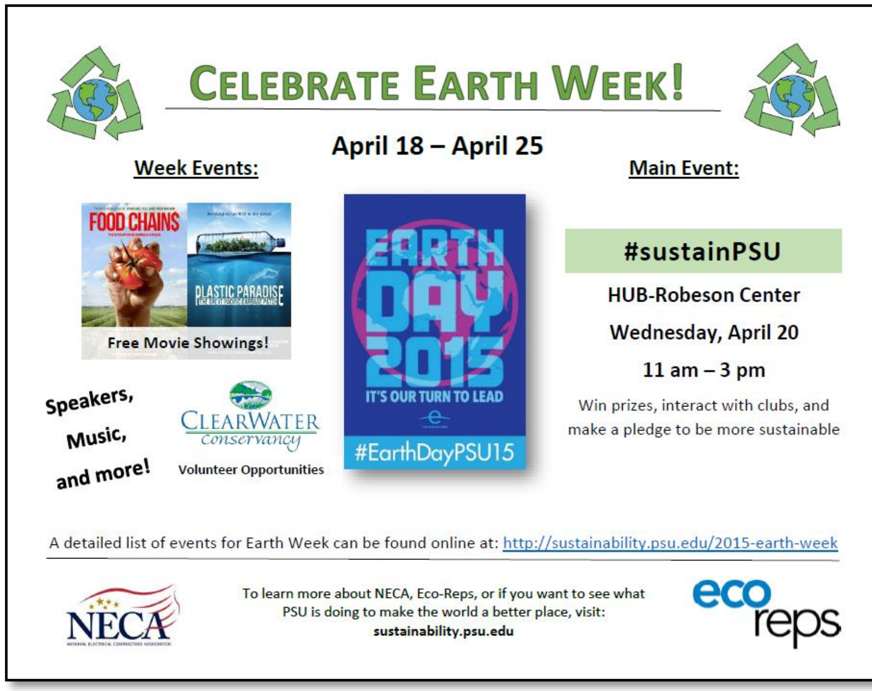


Figure 15:

Top Row: Both of the created flyers handed out to students promoting CCN and Earth Week, respectively.

Bottom Row: A freshman, mechanical engineering student made a picture pledge at our tabling event in Johnston Commons. He expressed an interest in energy conservation and NECA.

Testing and Feedback

Through our outreach efforts, we were able to gather some crucial feedback towards student's energy awareness and willingness to alter their behaviors. Our results varied widely on many accounts. When asked "Who won the East Halls Energy Challenge?" we had answers that ranged from the correct answer of "Stone Hall" all the way to theories on how Penn State is simply using this event as a ploy to further stuff their pockets with money. Here are some of our other results:

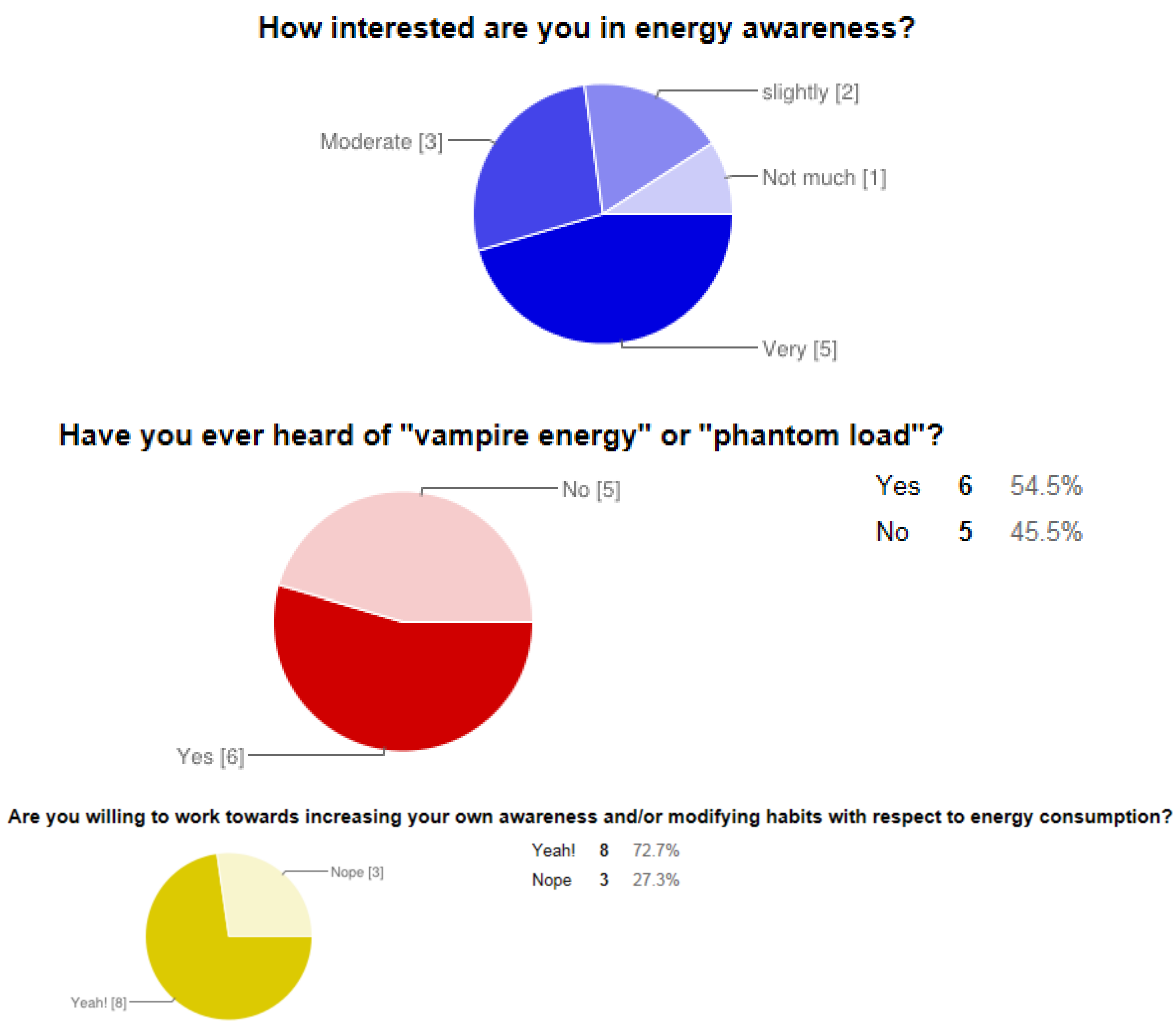


Figure 15.1, Figure 15.2, Figure 15.3

Overall, we believe we accomplished our goal of spreading awareness and getting people excited about energy conservation. Of course the absolute numerical impact from our efforts alone would be impossible to measure, but the impact we had on the people we educated and spoke with cannot be overlooked.

Future Plans

Unfortunately, much of what we wanted to accomplish in terms of outreach did not fully develop before the conclusion of the Green Energy Challenge. However, we are in line to succeed and extend our influence further than ever before.

In collaboration with Dr. Susan Stewart, an aerospace engineering professor at University Park, we are beginning developing a NECA component into their established Pennsylvania Wind for Schools program. This initiative encourages grade-school students to learn, explore, and develop interest towards renewable energy through wind. University students can volunteer for this event to help with the younger students' own wind competition and to further encourage educational success. This event will take place on May 2, 2015.

We specifically plan not only to participate in the above event, but our goal is to inspire further education via surveys and feedback procedures for the students, teachers, and parents alike. Other initiatives include, but are not limited to, the professional development of our student chapter members, tours of our very own Morning Star Solar Home, apartment energy audits, expanded roles in CCN next spring through additional residence complexes, and heavy recruitment for our student chapter leading into next year.

Feedback Letter from Client

PENNSTATE

Office of Physical Plant

The Pennsylvania State University
Physical Plant Building
University Park, PA 16802-1118

DATE: April 20, 2015

TO: GEC Team
Penn State NECA Student Chapter
310 Sackett Building, University Park

FROM: Pat Kasper

On behalf of the Penn State and Office of Physical Plant, I am glad to have had the opportunity to work with you all throughout the timeline of the Green Energy Challenge. From the start, our many conversations and level of contact have shown that you all have been dedicated to your cause and have shown great enthusiasm in your work.

Henning is a complex building with a strong importance to the Agricultural Sciences Program and the many researchers who work there, so your evaluation and your proposal are very important us who work with it daily. The building itself can get overlooked sometimes, but the significance it provides to our university is unmatched. I believe that your proposal works towards the future goals of Penn State's Sustainability Strategic Plan, most importantly without having to limit or sacrifice the needs of the building and its occupants.

Given the age and condition of the Henning Building, it was certainly nice to see it through a different scope. From the addition of PV panels above to the much-improved LED lights below, there is plenty to look forward to if these plans were to be implemented on any capacity. Not only would these features improve our personal energy profile, but they would serve as a vision and direction towards what other buildings should consider in the future here at Penn State.

Once again, it has been a pleasure to meet so many of you and I wish you the best of luck in the competition. Thank you again for your time and please inform me of your results once they are announced.

Sincerely,

Patrick Kasper

Pat Kasper
Area 5 Supervisor, Building Services
The Pennsylvania State University
116C Agricultural Engineering
University Park, PA 16802
814-769-3506

printed on recycled paper

An Equal Opportunity University

Article in Department/University Newsletter

On April 14, 2015, the following article was distributed in Penn State's student run daily publication, *The Daily Collegian*. The article was written by Ms. Madeline DePascale and was available both online and in print, which is shown below.

Online Article Link


LOCAL

Alumnus receives research grant

Alex's Lemonade Stand Foundation aids Tait Huso's leukemia research

NECA reassesses campus building

The National Electrical Contractors Association is proposing a more energy efficient building

Council discusses possible changes

The Fourteenth Annual Eberly Family Distinguished Lecture in Science

"Medicine and the (mis)Management of Evolution"

Friday, April 17, 2015

Figure 16: Article in *The Collegian*

If the power ever went out in the Henning Building, Penn State's student chapter of the National Electrical Contractors Association would know how to combat the problem in the most energy-efficient way possible.

Penn State students who are a part of NECA are members of the Penn-Del-Jersey chapter of NECA and have sponsors from people within the chapter itself and other business owners and professionals, NECA President Nick Kolesar said.

As part of their proposal for the Green Energy Challenge — a national challenge created by NECA for all student chapters — Penn State NECA Vice President Gabrielle Reese said members have been working all year long on an energy retrofit for the Henning Building.

Kolesar (senior-energy engineering and energy business and finance) defined retrofitting as examining a building's appliances and machinery to see if they are running inefficiently or if the building could benefit from updated systems.

"We have to propose an energy retrofit for a building on campus of our choice that has a critical load in it, meaning that if the power were to go out, it has a part that needs power all the time," Reese (junior-energy engineering) said. "We also want a micro grid so the building is generating its own electricity, so we're proposing a solar array with rechargeable batteries."

With the guidelines of the energy challenge, Kolesar said the goal is to "pick a building and retrofit it so we can give our proposal to the building supervisor and suggest green and sustainable applications for what they're looking for."

In order to properly analyze the building, Reese said members are split up into four teams: micro grid/critical load, light analysis, energy audit and construction management.

Kevin Clement, former NECA president, is the leader for the construction team this year and said their job is to create new ways to make a building more sustainable and make sure the proposed ideas are feasible and could potentially help the client to save money over time.

“Whenever a system like solar panels is put in, [the client] gets money back within a certain amount of time,” Clement (senior-architectural engineering) said. “Whatever we install, we need to make sure the initial cost of the idea is paid back by the savings within a 10-year limit, so that way it can be done for Penn State.”

He said since the Henning Building is going to get renovated in the near future at Penn State, he would like to see some of their ideas implemented into the new building.

“[In the past] we proposed a lighting system for the Fraser Street parking garage, and this past year they installed LED fixtures which may have been because they saw our proposal and saw they were able to save money,” Clement said.

Reese said once the proposal is submitted, a panel of judges will review it over the summer and then they will find out if their proposal made it into the top three.

“The top three teams go to a national NECA conference in San Francisco,” Reese said. “If we place, the officers and two other members will get to go. It’s a really good opportunity for networking and reaching out to higher people and meeting other companies partnered with NECA to see what’s going on in the real word.”

Local NECA Chapter Interaction

A Note from the NECA, Penn-Del-Jersey Chapter

Helen Levins

NECA, Penn-Del-Jersey Staff Member

The 2014-2015 NECA Student Chapter at Penn State University never ceases to impress me with their dedication to the club and the Green Energy Challenge. While our chapter's office is located over three hours away from their campus, the Penn State students are active in the student chapter and they make every effort to keep a friendly working relationship with our contractors and staff.

Figure 17: Interaction with PDJ NECA Chapter

This fall, a group of our contractor members traveled to Penn State University for our annual football weekend. The Student Chapter members welcomed us to their campus and attended many festivities with our members. Students networked with our members and listened to guest speakers from NECA and the IBEW at our Friday night dinner. Some students were presented with scholarships from our Chapter for their exemplary dedication to the NECA organization. In the morning, the students joined us for a tour of the MorningStar Solar Home. MorningStar is a net-zero home that serves as a teaching and research hub for renewable energy systems and energy efficient technologies and it was funded in large part by NECA and ELECTRI International. Afterwards, our NECA group took part in one of Penn State's best traditions, a lively football game.

When I first joined NECA in December, our Student Chapter's president reached out to me on the phone to discuss his experiences and the future of the club. He encouraged me to visit campus; in February, I was able to make the trip. The student chapter welcomed our Executive Director and me to one of their weekly student meetings on campus. We discussed internships, the Green Energy Challenge, how to get involved, and elections as we ate pizza together. In the following weeks, the chapter held elections and the new leaders of the organization were quick to contact me to discuss their vision.

Through their work on the Green Energy Challenge, the students have requested even more interaction with our contractors. In response, four of our contractors volunteered to mentor the Green Energy Challenge subgroups on their portion of the projects and provide industry expertise. The students are truly making the most of the resources that NECA has to offer.

I am proud to oversee the NECA Student Chapter at Penn State University and I hope to have the chance to see them present their work to the entire NECA community in October.

Acknowledgements

We would like to thank the following for their support, dedication, and assistance throughout the year. Without them, none of this would have been possible.

Helen Levins

Jeff Scarpello

Pat Kasper

David Riley

Dan Cohee

Jason Moore

Dick Harris

Mike Prinkey

<u>NECA Members</u>

Dian Pan

Leighton Young

Mohammed Kanbari

Chris McCleary

Steve McGowan

Jake Skrzat

Joe Hacker

Jackie Eury

Kiley Johns

Appendix

	EXISTING VERSUS RETROFIT FIXTURES								
	Scheduled Hours (Weekly)	Existing Fixture	Number of Fixtures	Wattage	Existing Consumption (kWh)	Retrofit Fixture	Number of Fixtures	Wattage	Retrofit Consumption (kWh)
INTERIOR	60	2X4 Parabolic 3L	233	96	1342	2RTL4R	233	38.52	539
	60	2X4 Parabolic Industrial	342	96	1970	2TLED	342	50	1026
	60	2X2 Parabolic U-tube	9	93	50	2RTL2R	9	40.08	22
	60	2X2 Parabolic 3L	40	84	202	2RTL2R	40	40.08	96
	60	1X4 Parabolic 2L	76	64	292	RTL	76	40.68	186
	168	1X4 Industrial 2L	159	64	1710	TLX4	159	46	1229
	60	Display	3	80	14	TL4	3	30	5
	60	1x1 Square Fixture	2	20	2	RT5D LED	2	41	5
	60	Luminous Ceiling	2	480	58	Cubic-A2	2	137	16
	168	Stairwell Fixture	18	64	194	TLX4	18	46	139
	168	Exit Signs	13	14	31	EDG	13	2.5	5
EXTERIOR	91	Lamp Post	1	100	9	Louis Poulsen KIPP 416 Luminaire models	1	100	9
	91	Wall Pack	3	100	27	LED Mini Wall Sconce	3	9	2
	91	Square	3	20	5	CREE LED Light Bulbs	3	11	3
		Total Number of Fixtures:	904	Total kWh:	5906	Total Number of Fixtures:	904	Total kWh:	3282
				Annually:	289374			Annually:	160842
				Cost:	$ 72,343.60			Cost:	$ 40,210.40

COST BENEFITS		
kWh/Yr Saved	Annual Savings	5 Year Savings
128,532.80	$ 32,133.20	$ 160,666.00

Figure 18: Energy Analysis

Description	Description	Specification	Quantity	Wattage (W)	Lumens	CCT (K)	Dimming
2RTL4R	2X4 Parabolic 3L	RL1A (Kit)	233	38.52	4000	4000	yes
2TLED	2X4 Parabolic Industrial	RL1B	342	50	4000	4000	yes
2RTL2R	2X2 Parabolic U-tube	RL2 (Kit)	9	40.08	4000	4000	yes
2RTL2R	2X2 Parabolic 3L	RL2 (Kit)	40	40.08	4000	4000	yes
RTL	1X4 Parabolic 2L	RL3	76	40.68	4000	4000	yes
TLX4	1X4 Industrial 2L	SL1	159	46	4000	4000	yes
TL4	Display	RL5	3	30	4000	4000	yes
RT5D LED	1x1 Square Fixture	RL4	2	41	4000	4000	yes
Cubic-A2	Luminous Ceiling	RL6	2	137	4000	4000	yes
TLX4	Stairwell Fixture	SL1	18	46	4000	4000	yes
EDG	Exit Signs	EX1	13	2.5	4000	4000	yes
Louis Poulsen KIPP 416 Luminaire models	Lamp Post	XL1	1	100	4000	4000	yes
LED Mini Wall Sconce	Wall Pack	XL2	3	9	4000	4000	yes
CREE LED Light Bulbs	Square	XL3	3	11	4000	4000	yes

Figure 19: Fixture Schedule

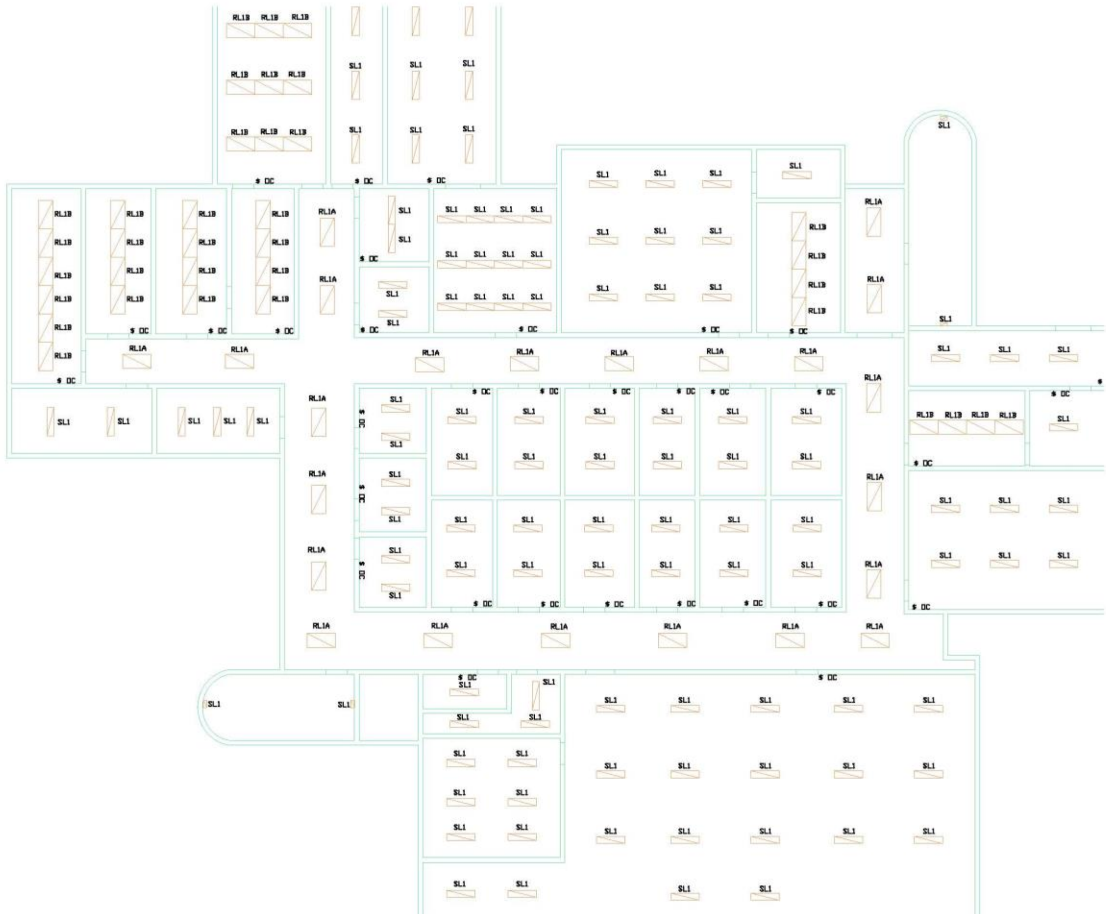


Figure 20

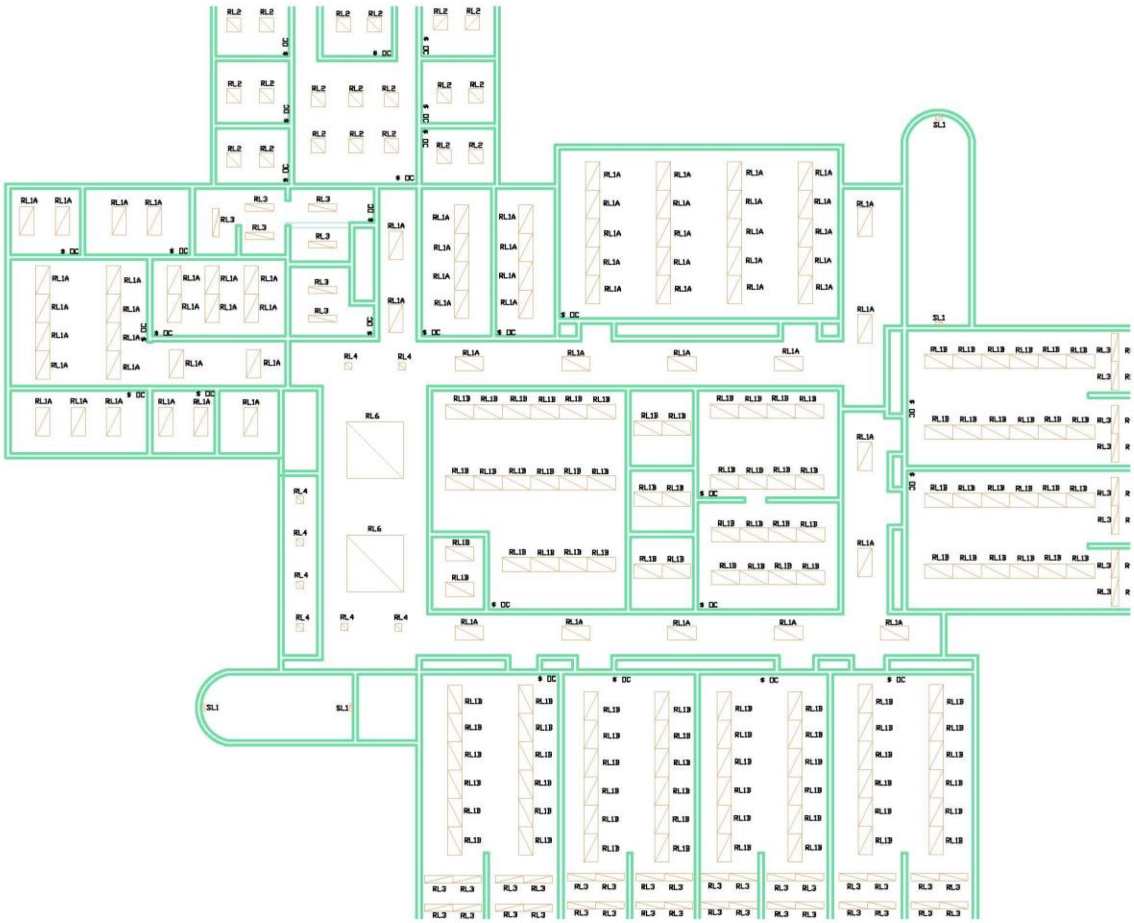


Figure 21

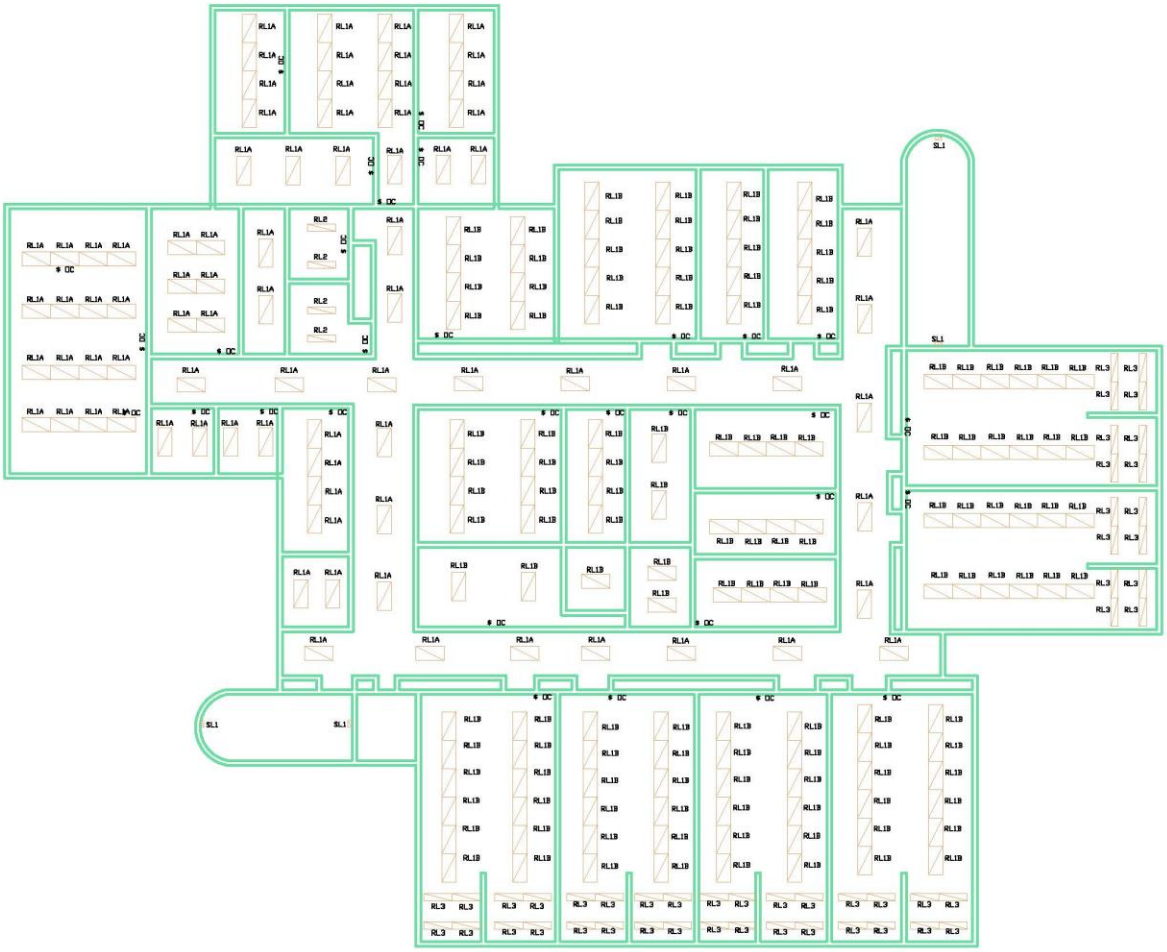


Figure 22

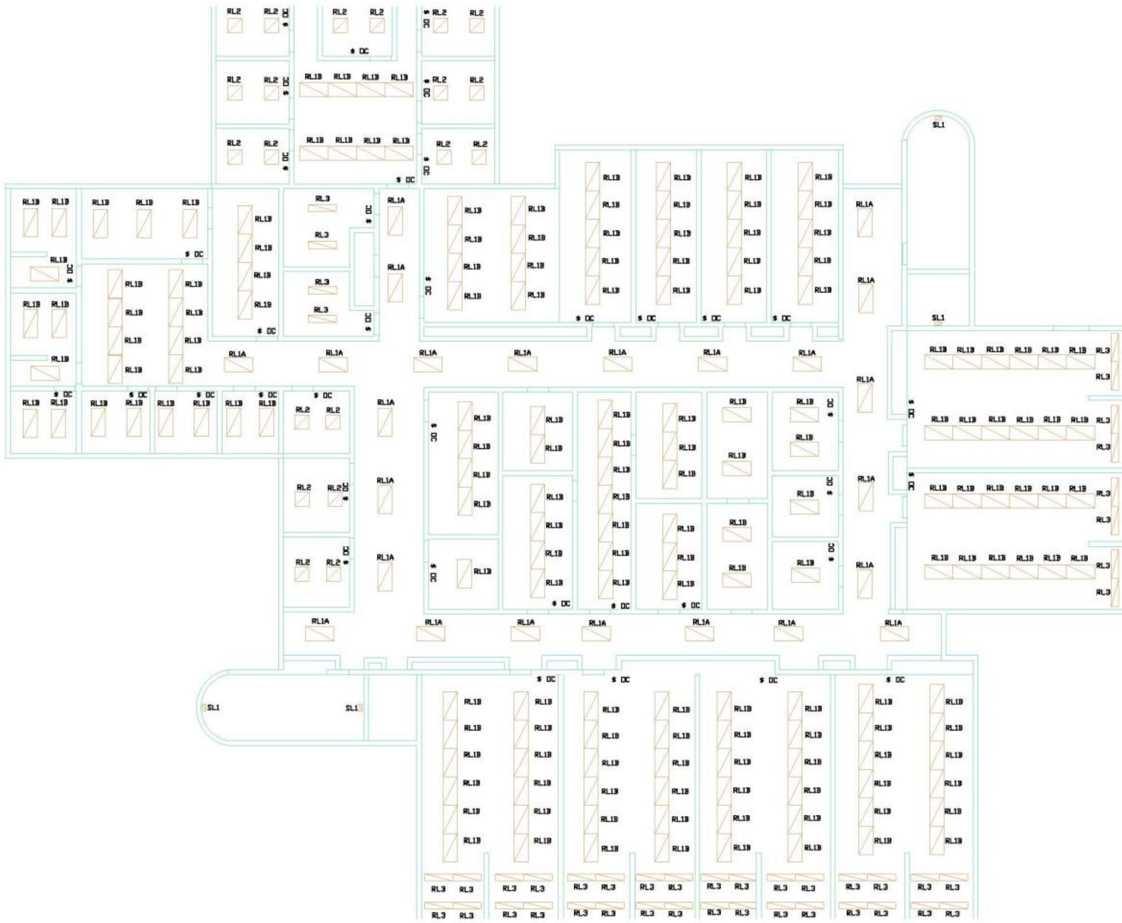


Figure 3